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The Black Flies of New York State

(Diptera: Simuliidae)

BY

ALAN STONE

Entomology Research Branch

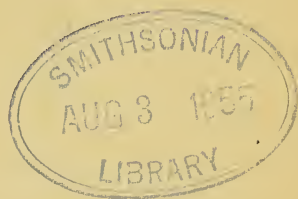
Agricultural Research Service

United States Department of Agriculture

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HUGO A. JAMNBACK

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CORRECTION SLIP

Dissected specimens, mounted on slides, were used in describing the mouth parts of Twinnia tibblesi larvae. Closer examination of whole specimens shows that the structures described as "mouth brushes" or "cephalic fans" (which, when present, are derived from the lateral portions of the labrum) are actually brushlike setae originating from the median "palatum" of the labrum. Corrections 1 to 4 are text references to this structure.

1. Page 17, larval key, couplet 1, line 1, for "mouth brush present, but inconspicuous, with fan rays shorter than antenna;" read "mouth brush absent."
2. Page 18, paragraph 3, line 2, for "mouth brush very inconspicuous with fan rays shorter than antenna;" read "mouth brush absent."
3. Page 18, paragraph 6, line 9, delete "and the presence of mouth brushes, even though reduced, in the larva."
4. Page 20, paragraph 2, line 20, for "Each cephalic fan with about 36 rays" read "Cephalic fan absent."
5. Page 77, for heading "The Simultum venustum complex" read "The Simulium venustum complex."

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INTRODUCTION

Black flies are blood-sucking Diptera of public health and economic importance. Besides being disease carriers, they are annoying to man and domestic animals because of their biting and crawling habits. Livestock may even be killed by heavy attacks of black flies. It is probable that, next to mosquitoes, black flies are the most annoying insect pests of man in New York State. The importance of the State as a vacation area makes such pests of particular importance, although their effect on the resident population and on domestic animals is likewise well worth serious consideration.

Recent taxonomic studies on the family Simuliidae in this country have greatly increased the number of known species. They have also shown that many of these species are rather difficult to distinguish unless all of the stages are known. Because of these facts, some of the early biological work, based upon erroneously determined material, is of little value. Without doubt a number of the species now known from other parts of the Northeast will be found in New York State, but we have confined this work to the 23 species actually collected in the State.

In order to develop and carry out effective control programs it is necessary to know which species are important and how they live. It is the purpose of this publication to facilitate the determination of the New York State species of black flies and to give some idea of their distribution and habits.

The economic importance and control of black flies are considered in a separate New York State Museum Bulletin by Jamnback and Collins.

Figures 1-32 and 48-74 were drawn by Arthur D. Cushman, Entomology Research Branch, United States Department of Agriculture; figures 34-38, 40, 43-47, and 75-113 by the junior author; figures 33, 39, 41, and 42 by the senior author. Photographs 114-116 were taken by the junior author.

We express our gratitude to the following persons and institutions, not acknowledged elsewhere in the text, for assistance in this work:

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CHARACTERS USED IN CLASSIFICATION AND DETERMINATION

While we do not intend to present here a complete study of the anatomy of black flies, we include this section in order that the keys and descriptions can be used with understanding. More important anatomical studies include those by Krafchick (1943) and Nicholson (1945) on mouthparts, Freeman (1950) on the male genitalia, and Puri (1925) on the larvae and pupae.

ADULTS

Head (fig. 1). The *eyes* of the female are separated by the *frons* which is usually narrowest just above the antennae and widened upward. The male is usually holoptic, and the larger upper facets are sharply differentiated from the smaller lower ones. The *antennae* are located in a widened area between the eyes and are usually 11-segmented, rarely 9 or 10-segmented. The first segment, or *scape* and the second, or *pedicel*, are usually less closely united than the usual nine segments of the *flagellum*. Below the antenna is the convex *clypeus*, and below this the tapering *labrum*, which bears teeth at the apex. The *mandibles* are broad, flat plates, usually serrate on both edges, and the *maxillae* are more slender and usually have retrorse teeth on their margins. A few species, such as *Cnephia dacotensis*, have the mandibles and maxillae unarmed. The maxillary *palpi* are five-segmented, the first two segments short, the third usually enlarged and containing a *sensory organ*, the fourth slender and rather short, and the fifth usually the longest. The pharyngeal structures may show some usable characters, although we have not determined this for our species.

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Thorax (fig. 4). This is rather strongly convex above, giving the fly a hump-backed appearance, particularly in the male. The *scutum* may have a characteristic pattern of pollinosity or hairs. Frequently a pair of spots near the anterior margin, the sides and the prescutellar declivity are paler in color. The color pattern is largely structural so that the pattern varies greatly with the angle of incidence of the light. There is also a strong sexual dimorphism, in the color pattern. The males are usually much darker and more velvety in appearance, with the anterolateral scutal spots standing out in greater contrast. The *postscutellum* is the convex sclerite lying between the scutellum and the base of the abdomen. The pleuron is rather uniform in the family, although there may be some difference in the arrangement of fine hairs on the sclerites. The color of the *pleural tuft* (beneath the wing base) may be characteristic.

Wings (fig. 2). These have a characteristic venation, the thickened veins being concentrated anteriorly on the rather broad wing. The *costa* ends with the *radial sector* before the apex of the wing. The *basal vein* is short and stout and basad of the *humeral crossvein*. The color of the hairs on the basal vein and on the base of the costa is often diagnostic. The *subcosta* is complete, joining the costa, and it often has hairs on the under surface. The *radial vein* (R) extends from the end of the basal vein to the point where it divides into vein R₁ and the radial sector (R_s), and it is pilose above in *Twinnia*, *Prosimulium*, *Cnephia* and *Simulium* (*Eusimulium*). The radial sector has two branches in *Prosimulium* and *Twinnia* and rarely in *Cnephia*, and it is unbranched in *Simulium*. The anterior veins bear only fine, hairlike macrotrichia in *Twinnia* and *Prosimulium*, while in *Cnephia* and *Simulium* these are mixed with short, spinelike macrotrichia. The rest of the wing venation is as figured and shows no diagnostic characters in our genera, except in the presence or absence of the small *basal cell*.

Legs. Characters in the legs are both tinctorial and structural. *Twinnia*, *Prosimulium* and *Cnephia* usually have rather uniformly colored legs, while most *Simulium* have a distinct pattern of pale areas on the coxae, tibiae and tarsi. The tibiae are usually somewhat flattened and the shape of the hind tibia may be significant. The tarsus consists of a long basitarsus, and four shorter segments, the fourth segment being short and bilobed. The apex of the hind basitarsus is usually produced posteriorly as a flattened lobe, the *calcipala*, and in *Simulium* the second hind tarsal segment has a dorsal notch, the *pedisulcus*. The claws of the female are variously shaped, often with subbasal teeth or basal lobes.

Abdomen. The first abdominal tergite is modified as a basal scale, from which arises the usually long hairs of the *basal fringe*. In most species the sclerotized tergites are reduced on the intermediate segments, enlarging progressively posteriorly. The vestiture and polinosity of the abdomen are often of value in determination. In females, sternites 2 to 7 are usually unsclerotized. The *ninth tergite* of the female (fig. 3) is broad and narrowly attached laterally to the arms of the genital fork. The *genital fork* is a Y-shaped internal structure, with the stem heavily sclerotized and anteromedian in position, and the arms are variously shaped and irregularly sclerotized, often with dorsal or ventral projections. The *eighth sternite* is more or less sclerotized, its shape being somewhat diagnostic, and projecting posteriorly from this are the two lobes of the *ovipositor* or anterior gonapophyses. On each side of the anus are sclerotized *anal lobes* and posterior to these the paired *cerci*. The shape of the genital fork, ovipositor, anal lobes and cerci are of some taxonomic value. In the male the sternites are all more or less sclerotized. The male genitalia (figs. 11 and 12) provide excellent characters for specific determination, although their small size and their thickness make full utilization of the structures rather difficult. It has been customary to depend upon the dististyles and ventral plate principally for specific characters, and the drawings given in this paper of the species omit the more dorsal structures. The *parameres* and the hooks on the *parameral arms*, the *dorsal sclerite* and the *median sclerite* are also often of value, and can best be seen in cleared specimens in glycerine. The *basistyle* is usually short and stout and shows little variation. The *dististyle* has a wide variety of shapes in the different genera and species. The *ventral plate* or adminiculum is heavily sclerotized and variously shaped. It is usually concave dorsally with the apex curving ventrally, resembling the lip of a pitcher, and it may be heavily pilose or armed with teeth laterally; the basal projections of the ventral plate are variously shaped and may have lateral prongs. The parameres are a pair of sclerotized plates from each of which arises a slender arm, usually bearing teeth of various sizes.

PUPAE

Cephalothorax. The surface is usually relatively smooth, although in certain species it may be distinctly rugose. There are a few sensory hairs, the *trichomes*, usually directed forward, and either simple or branched. On each side of the thorax there is a *respiratory organ*, and the shape of this structure is of great value in determining species. In most species there is a regular number of slender filaments

with characteristic arrangement, but in some these may be thickened or irregularly branched.

Abdomen. This is armed with recurved hooks in one or more rows on both the tergites and the sternites of some of the segments. These are of some use in group classification and possibly also in species determination. The tip of the abdomen dorsally has a pair of strong acute projections, the *terminal hooks*, in *Twinnia*, *Prosimulium* and some *Cnephia*. In other *Cnephia* and in *Simulium* these are greatly reduced or absent.

Cocoon. The shape of the cocoon is often very characteristic for the species. In *Prosimulium*, *Twinnia* and some *Cnephia* it is an irregular, shapeless covering over part or all of the pupa. In other *Cnephia* and in *Simulium* the cocoon is well formed and may be wall-vase-shaped (see fig. 70), the sides not connected anteroventrally below the head, or boot-shaped, with a distinct connection anteroventrally. The sides of the cocoon may be solid or may have one or more lateral apertures.

LARVAE

(Fig. 75)

Head. The *head capsule* is made up of two sclerites, the dorsal *frontoclypeus* and the lateral and ventral *epicranial plate*. The frontoclypeus is uniform in color except for the *head spots*. The head spots occur at the points of attachment of muscles to the head capsule. In some species, the area around the head spots may be fulvous. Since the location of the head spots on the frontoclypeus is constant in most of the species studied, they may be divided into four categories based on their locations: the *anterior median group*, the *posterior median group*, and the paired *anterior lateral* and *posterior lateral groups* (fig. 78). In some species, the head spots are light against a dark background, in others dark against a lighter background. The epicranial plate is less uniform in color than the frontoclypeus. Often the lateral portion is somewhat darker than the ventral. There are a series of muscle attachment points along the posterolateral margin of the epicranial plate. Three spots may be visible, arranged in an irregular line on each side, extending from near the posterolateral margin anteriorly to a point below the eye. In some species there is a single lateral spot on each side of the ventral surface slightly anterior to the apex of the throat cleft.

The *throat cleft* or epicranial cleft is located on the posteroventral margin of the epicranial plate. It may vary in shape, width, and length between species (figs. 89-97).

The *suboesophageal ganglion* is located just ventrad of the digestive tract just under the epidermis in the general region of the throat cleft. It is a distinct black in some species and either white or light brown in others (figs. 93, 95).

The *submentum* bears heavily sclerotized teeth on the anterior margin. These are fused to the anteromedian margin of the epicranial plate. The shape, size and number of teeth of the submentum are slightly variable but nevertheless furnish good generic and sometimes specific characters. The degree of serration of the lateral margins of the submentum is also of some value in distinguishing species (figs. 81-88).

There are two series of setae which appear to originate near the lateral margins of the submentum. Actually, as was pointed out by Puri (1925), they originate on the epicranial plate just ventrad of the submentum. Earlier workers described these as submental or labial setae. These setae will be referred to as *epicranial setae* in the larval descriptions. The number of setae and the distance from the outermost tooth of the submentum to the anteriormost seta on the same side are of some taxonomic value.

The *mandibles* of many species have been well described by Puri (1925). There are a series of teeth and serrations on the distal portion of the mandible which are of some value in identifying genera, subgenera and species. Puri divided these teeth into four groups. There are three large, black *apical teeth* which are stout in most species. The basal tooth of these three is about twice as large as the upper two. Basad of the apical teeth there is a series of *small teeth* on the ventral surface of the mandible. The first three of these are similar in appearance to the apical teeth but are usually much less heavily pigmented. They project clearly beyond the inner edge of the mandible and are not overlapped by other teeth. Their relative lengths vary between species but are fairly constant within each species. Basad of these three teeth the series of small teeth is continued by less distinctly visible teeth which gradually decrease in size from anterior to posterior. This series of teeth is overlapped by a submarginal row of *bristlelike teeth* which begin just basad of the third tooth of the series of small teeth. The first tooth of this bristlelike series is usually longer than the third tooth of the small teeth series. The bristlelike teeth decrease gradually in size from anterior to posterior. Since all but the first three teeth of the small teeth series overlap the bristlelike teeth, it is difficult to determine the number and size of either of these series without clearing, staining and examining a number of specimens under oil immersion. The edge of the inner subapical margin of the mandible

may bear *serrations* (toothlike processes of Puri, 1925). These serrations are variable, even within a species, but the basic pattern usually remains recognizable.

The *antennae* are generally four-segmented. (Some authors have considered segments 1 and 2 as a single compound segment.) Segment 2 bears two small spinelike distal processes. Segment 4 is very short and pointed apically. The pigmentation and the total length of the antennae are characters of some taxonomic value. The segment length ratios are somewhat variable within species but have some taxonomic value (figs. 98-107).

The *cephalic fans* are complex paired structures homologous to the mouth brushes of mosquito larvae, attached to the sides of the labrum and located laterad of the antennae. The number of fan rays is variable within a species, but the average number for a species often varies from that of other species. Sommerman (1953) used the shape of the secondary fan (under the primary fan) as a taxonomic character of generic value.

The *maxillae* are rounded apically, bearing numerous setae and bristles. The *maxillary palpi* are single segmented and bear stout apical bristles.

Thorax. This is somewhat stouter than the first few abdominal segments. In mature specimens, the developing pupal respiratory organ can be readily seen as a histoblast just under the epidermis on each side of the prothorax. These filaments may be removed for study as an aid in identifying larvae. A single median ventral proleg arises from the prothorax (although the base appears to extend into the mesothorax as a ventral thickening). This proleg terminates distally in rows of radially arranged hooks, similar in appearance to the anal hooks. Sommerman (1953) noted that the lateral plate of the proleg is of some value in identifying species of *Prosimulium*.

Abdomen. This is eight-segmented. The segments usually increase gradually in diameter from anterior to posterior with segment 7 the stoutest.

The *ventral tubercles* of the abdomen are paired conical projections from the lateroventral portion of the eighth abdominal segment. These may be conspicuous as in *S. (Eusimulium)* spp.; small and indistinct as in *S. (S.)venustum*; or totally lacking as in *P. hirtipes* and most of the other species found in New York.

The *anal gill* is a projection of the ventral wall of the rectum (Headlee, 1906). When retracted it lies completely within the rectal cavity. The rectal opening is located just anterior to the anal cross-piece on the dorsum of the eighth abdominal segment. The anal gill

may consist of three simple lobes (*Prosimulium* and *Cnephia*) or be made up of three compound lobes (all *Simulium* species found in New York except *S. (E.) aureum*). *S. (N.) vittatum* is distinguished by having very small ventral accessory lobes.

The *anal hooks* are located at the posterior end of the terminal abdominal segment. These hooks are arranged in a series of radially arranged parallel rows. The number of rows and the number of hooks per row, while difficult to count, are sometimes of use in taxonomy.

The *anal cross-piece* is located just anterior to the anal hooks of the eighth abdominal segment. It consists of two sclerotized pieces. Each piece is broadly U-shaped with the arms of one directed to the right and of the other to the left. These arms are joined medially, forming an X-shaped or Y-shaped structure. The comparative lengths of the upper and lower arms and the presence or absence of lightly sclerotized areas adjoining or between the arms are of some value in determining species although these may vary somewhat within a species (figs. 114-16).

GENERAL BIOLOGY

The egg-laying habits of most species of black flies are poorly known. Some species lay their eggs in masses on grass trailing in the water (e.g. *S. aureum*); others drop the eggs singly into streams (*S. arcticum*; Fredeen *et al.*, 1951); still others lay their eggs in long strings (*S. vittatum*). Comstock (1895) observed *S. pictipes* (as *S. innoxium*) laying eggs on rocks beneath a thin sheet of water. Oviposition of species observed generally took place in the late afternoon or early evening (Fredeen *et al.*, 1951; Jobbins-Pomeroy, 1916). However, Gambrell (1933) reported that oviposition of *S. pictipes* was observed between 9 and 11 a.m.

A black fly lays between 150 and 450 eggs. They are whitish to light orange when first laid, darkening as they mature, and are subtriangular in outline, ranging in length from 0.2 to 0.4 mm. The incubation period varies from about 2.5 days to more than 7 months. The eggs of species tested by Jobbins-Pomeroy (1916), Wu (1931) and Smart (1944) were not resistant to prolonged desiccation.

Larvae are found only in running water in this country. Some species occur primarily in rivers (*C. pecuaria*¹, *S. arcticum*, *S. reptans*, and *S. jenningsi*). It is interesting to note that all of these river species may be pests of economic importance at times. Some species are found in both large and small permanent streams (*S. venustum*, *S. tuberosum*,

¹ This name is here emended from *pecuarum* to conform with the proper Latin adjective in the feminine gender.

S. gouldingi). Other species are more catholic in their distribution, being found in large or small, permanent and temporary streams (*P. hirtipes*, *C. mutata*). Still other species are found almost exclusively below lake outlets, dams and large pools (*S. vittatum*, *S. decorum*, *S. aureum*, *C. dacotensis* and *P. magnum*). *S. pictipes* larvae are usually found in swift, permanent streams with sedimentary rock bottoms. *S. latipes* has been found only in small, shallow, semi-permanent streams.

Larvae of species studied by Puri (1925), Edwards (1920), Baranov (1935) and Cameron (1922) molt six times before pupation. Mature larvae range from 5 to 12 mm in length depending on the species and somewhat on the time of year. The duration of the larval period depends on the species, temperature of the water, season and amount of food available. DeFoliart (1951) reported a minimum larval developmental period of 12 days in the summer. *P. hirtipes*, *C. mutata* and *S. vittatum* overwinter as larvae in the Adirondacks. Most of the other species found in New York State probably overwinter in the egg stage (although overwintering eggs have not been found) and hatch in the spring or summer.

Pupae are found attached to the substrata in the same locations as the larvae. The larvae weave silken pupal cases which may be small and rudimentary (*Twinnia*), shapeless masses of silk (*Prosimulium* spp., *Cnephia dacotensis* and *C. mutata*), coarsely woven cocoons (*S. pictipes*, *S. decorum*), or closely woven cocoons of various shapes (*C. loisae*, *S. parnassum*, *S. venustum*, *S. tuberosum*, *S. (Eusimulium)* spp.). Usually the pupal case has the open end facing downstream. The length of the pupal stage ranges from two days to three weeks depending on water temperature and the species involved.

The feeding habits of the adults of most species are not known. Females of some species are known to suck blood from mammals and birds. Both males and females have been kept alive for long periods when fed sugar-water or soaked raisins. Wu (1931) kept adults of *S. vittatum* and *S. jenningsi* alive for five to six days on a diet of water and up to 18 days with sugar solutions or soaked raisins. At least two species (*C. dacotensis* and *P. alpestre*) do not feed as adults. According to Jobbins-Pomeroy (1916), *S. venustum* requires a blood meal for the development of eggs. Cameron (1922) reported that *S. arcticum* (as *S. simile*) also requires a blood meal. Wu (1931) reported that *S. venustum* apparently requires a blood meal while *S. vittatum* does not.

Because of the expense and large number of personnel required, few flight range studies of black flies have been carried out. Dalmat

(1950, 1952) and Dalmat and Gibson (1952) in Guatemala reported flight ranges of marked specimens of *S. metallicum*, *S. ochraceum*, and *S. callidum* up to 9.7 miles, although most of the specimens were collected at distances of less than four miles. Twinn (1952) reported that radioactive phosphorous (P^{32}) is being used in studies of the dispersal and flight range of black flies in Saskatchewan.

Flight range studies based on the distance from the nearest known breeding areas are less reliable because the flies may have migrated from streams further away or from closer but unknown breeding areas. However, the flight ranges of species which pass the immature stages in large rivers can be determined fairly accurately. Cameron (1922) reported taking *S. arcticum* (as *S. simile*) in large numbers 12 to 15 miles from the nearest known breeding area. Baranov (1937) recorded *S. colombaschensis* (as *S. columbaczense*) being collected 60 to 160 miles from the nearest known breeding places. Underhill (1944) reported taking *S. jenningsi* (as *S. nigroparvum*) in large numbers 10 miles from the nearest known breeding area and in smaller numbers 20 to 30 miles away. Wanson and Henrard (1945) have collected *S. damnosum* regularly 12 miles from the nearest known breeding place. Gibbins (1934) and Wanson (1950) reported collecting *S. damnosum* 30 to 50 miles from the nearest known breeding area. Rempel and Arnason (1947) reported collecting *S. arcticum* 50 miles from the breeding area, with an indicated range of 80 to 90 miles.

It is more difficult to determine the flight range of species which pass the immature stages in smaller (and usually more numerous) streams. Edwards (1920) reported taking *S. venustum* two miles and *S. ornatum* one mile from the nearest known breeding area. Jobbins-Pomeroy (1916) collected *S. johannseni* and *S. meridionale* (as *S. forbesi*) five to six miles from the nearest known breeding place.

COLLECTING, REARING AND STUDY

The taxonomic study of black flies presents certain special problems arising from the rather specialized habitat of the immature stages, the relatively small size of the adults and the presence of species groups in which it is difficult to recognize the species unless several stages are available. The pupae of black flies, however, are usually readily distinguishable, and it is not difficult to associate pupae with both the larvae and the adults, as will be explained below.

COLLECTING

Adults all too frequently come to the collector and can be taken by sweeping a net around the head, by putting a killing bottle over the

biting females or by capturing crawling specimens in a vial of alcohol. They may also be collected from domestic animals, particularly in the ears. Both males and females will come to light traps, and specimens can often be collected by sweeping vegetation in the vicinity of their breeding areas. The best method, however, is the rearing of adults from pupae.

Larvae and pupae are almost always found in flowing water, and usually that with a rather swift flow. Since species vary in the types of streams they inhabit, they should be searched for in everything from large rivers to tiny trickles, and at depths from half an inch to several feet. They are found attached to all sorts of objects, including sticks and branches, dead leaves, vegetation trailing in the water, and stones, from rather small pebbles to the bed rock of streams. They may occur in large masses or be very scattered. Often several species will be found mingled together in a single stream. Both larvae and pupae should be collected, if present.

REARING

Rearing from eggs or larvae requires special equipment and flowing water, and is not usually practicable under field conditions. Emergence traps have been used for collecting adults from streams. Positive association of the adults with the immature stages, however, is not possible by this method. Rearing from isolated pupae is not at all difficult. The pupa to be reared should be carefully removed from the stream, if possible without taking it from the surface to which it is attached, and placed on damp blotting paper, paper toweling, Cellucotton, or absorbent cotton, in a vial. It is important that this is kept damp, but it should not be wet. If older, darker pupae are selected, emergence should occur within a few days. The adult should be allowed to harden several hours; then it can be preserved in alcohol with the associated pupal skin or it can be killed dry and mounted.

STUDY

The value of the pupa in the taxonomic study of black flies lies in the relative ease of associating this stage with both the larva and the adult. It is often possible to dissect out fully developed adults of either sex. It is also possible to see in fully grown larvae the developing respiratory organs (histoblasts) of the pupa. It is often necessary to dissect out this pupal histoblast from the side of the larva. Frequently one also finds in the anterior part of the cocoon the shed head capsule of the larva, which again provides a tie between larval and pupal

characters. This makes possible the utilization of a much larger number of specific characters than can be found in one stage alone.

For studying the adults, both pinned dry specimens and those preserved in alcohol are useful, for different reasons, although if only one can be obtained, the specimen preserved in alcohol is preferable. It does not show the often distinctive color pattern as well as do dry specimens, but it is much easier to observe the structural characters. It is often necessary to make slide mounts of mouthparts, genitalia, tarsal claws and larval head structures. Both male and female genitalia can often be more clearly understood in cleared, whole preparations, preserved in glycerine, since the relationship of the parts is easier to observe in them. However, in order to see the minute, but often significant, details, dissection of the parts and mounting them on slides is necessary.

TAXONOMY

The generic classification of the Simuliidae is still unsettled, because little work has been done on a world-wide scale and there is still a great deal to be learned about the immature stages and life histories. We have adopted the rather conservative course of recognizing for New York State only four genera and six subgenera. These are *Twinnia* (a new genus); *Prosimulium*; *Cnephia* with the subgenera *Cnephia*, *Ectemnia* and *Mallochianella*; and *Simulium*, with the subgenera *Simulium*, *Neosimulium* and *Eusimulium*. The new genus is related to both *Prosimulium* and *Gymnopsis*, but appears to be sufficiently different from both to warrant generic rank. There is some difference of opinion about *Eusimulium*, some workers considering it as a full genus, at least for *aureum* and its relatives, and this may be justified, but until all of its presently included species can be more thoroughly studied we prefer to leave it in the genus *Simulium*. The genus *Cnephia* is even less homogeneous than *Simulium*, and the three New York State species are quite divergent. *Cnephia dacotensis* appears to be closely related to *C. pecuaria*, the genotype, although differing in mouthparts and habits; the other two species satisfactorily key to *Cnephia* in current keys to the adults, but diverge rather widely in the immature stages.

KEYS TO GENERA

Adults

- | | |
|---|---|
| 1 Macrotrichia of anterior wing veins all hairlike, not intermingled with spiniform ones; radial sector forked (<i>Prosimuliinae</i>) | 2 |
| — Macrotrichia of anterior wing veins mixed, hairlike and spiniform; radial sector rarely forked (<i>Simuliinae</i>) | 3 |

- 2 Antenna 9-segmented; ovipositor short, not extending beneath anal lobes
Twinnia, n. gen.
- Antenna 11-segmented; ovipositor longer, extending beneath anal lobes
Prosimulium Roubaud
- 3 Second hind tarsal segment with a deep pedisulcus; vein R with or without setae dorsally; basal cell absent.....*Simulium* Latreille
- Second hind tarsal segment without pedisulcus, or this represented by a shallow depression only; vein R with setae on dorsal surface; basal cell present.....*Cnephia* Enderlein

Pupae

- 1 Cocoon irregular, closely appressed to pupa, without any clearly defined anterior margin; abdomen with strong terminal hooks..... 2
- Cocoon well developed, variously shaped, usually with a clearly defined anterior margin; abdomen without large terminal hooks..... 5
- 2 Tergites 6 to 8, at least, each with an anterior row of fine hooklets..... 3
- Tergites 6 to 8 without an anterior row of fine hooklets.....*Twinnia*, n. gen.
- 3 Respiratory filaments arising from a rounded knob on a short petiole
Cnephia (*Cnephia*) Enderlein
- Respiratory filaments not arising from a rounded knob on a short petiole.. 4
- 4 Respiratory filaments less than 14, arising from two main trunks
Cnephia (*Mallochianella*) Enderlein
- Respiratory filaments usually more than 14, if less, not arising from two main trunks.....*Prosimulium* Roubaud
- 5 Cocoon stalked; anterior margin not clearly defined
Cnephia (*Ectemnia*) Enderlein
- Cocoon not stalked; anterior margin clearly defined.....*Simulium* Latreille

Larvae

- 1 Head capsule with strongly convex lateral margins; mouth brush present, but inconspicuous, with fan rays shorter than antenna; teeth of submentum and mandible rounded; anal cross-piece Y-shaped.....*Twinnia*, n. gen.
- Head capsule with slightly convex lateral margin; mouth brush conspicuous, with fan rays longer than antenna; teeth of submentum and mandible pointed; anal cross-piece X-shaped or absent..... 2
- 2 Antenna with segments 1 and 2 colorless, segments 3 and 4 dark brown to black; throat cleft a subrectangular notch, two to three times as wide as long; median tooth of submentum trifid; anal gill with three simple lobes.....*Prosimulium* Roubaud
- Antenna with segments 1 and 2 yellow to brown, segments 3 and 4 rarely dark brown; throat cleft neither a subrectangular notch nor two to three times as wide as long; median tooth of submentum single; anal gill with either three simple or three compound lobes..... 3
- 3 Submentum with large and subequal outer and median teeth and three smaller subequal intermediate teeth on each side; anal gill with three compound lobes (except *S. aureum*).....*Simulium* Latreille
- Submentum not as above; anal gill with three simple lobes..*Cnephia* Enderlein

SUBFAMILY PROSIMULIINAE

TWINNIA, NEW GENUS

Generic characters. Adults. Antenna 9-segmented; frons and occiput of female broad, the eyes being somewhat reduced; a protuberance behind eye of female; male holoptic, the dorsoanterior facets enlarged. Thorax with fine hairs, no bristles. Wing venation as in *Prosimulium*; radial sector forked; all macrotrichia of anterior wing veins hairlike; fold between veins M and Cu forked; anal vein broadly curved twice; basal cell present. Legs uniformly colored; no calcipala; no pedisulcus; hind tibia of male distinctly clavate; hind basitarsus of male considerably broadened. Ovipositor short, not reaching anal lobes. Ventral plate of male genitalia broad; dististyle with a single tooth.

Pupa. Respiratory organ multibranched; dorsal hooklets of abdomen greatly reduced; no row of fine hooklets on anterior margins of tergites 6 to 8; sternal hooklets strong; terminal hooks large. Cocoon very thin, shapeless, closely appressed to body.

Larva. Head capsule with strongly convex lateral margins; mouth brush very inconspicuous, with fan rays shorter than antenna; teeth of submentum and mandible rounded; mandible lacking teeth on outer subapical margin; anal cross-piece Y-shaped.

Genotype. *Twinnia tibblesi*, new species.

Included species. *Twinnia nova* (Dyar & Shannon) (= *Prosimulium novum* Dyar and Shannon, 1927:5). New combination.

This genus obviously belongs to the Prosimuliinae. The adult appears to be more closely related to *Prosimulium*, but the larva resembles *Gymnopaïs*. The 9-segmented antenna, protuberance behind eye, and reduced ovipositor of the adult, the reduction of hooklets on the dorsum of the abdomen of the pupa, and the head shape, reduced mouth brush, and the Y-shaped anal cross-piece of the larva, all clearly separate the genus from *Prosimulium*. The absence of stout setae on the thorax of the adult, the character of the respiratory organ of the pupa, and the presence of mouth brushes, even though reduced, in the larva, distinguish it from *Gymnopaïs*. When the larva was first discovered it was thought to be a *Gymnopaïs*, but the discovery of the pupae with head capsules of the larvae within the cocoons settled the matter. Only the female of *T. nova* is known, but it agrees very well with the generic characters we have given except that the protuberance behind the eye is less developed.

We take great pleasure in dedicating this genus to Dr C. R. Twinn, whose work on the species of eastern Canada is one of the outstanding contributions to our knowledge of the black flies of this continent. The work that led to the discovery of the pupae and adults of the type of this genus was directed by Doctor Twinn.

***Twinnia tipplesi*, new species**

(Figs. 17, 33, 55, 76, 79, 81, 89, 98, 115)

Female. Length 2.5-4 mm. General color blackish brown. Wing length 3.25-3.75 mm. Head gray with pale yellowish hair; width of frons about as great as length of first two antennal segments, widened above. First three antennal segments about 0.8 length of last six. Palpus dark; ratio of last three segments 2-2-3. Mouthparts very short; margin of mandibles not serrate; maxilla without teeth. Scutum brownish black, clothed with recumbent yellow hair. Scutellum with dense, erect yellow hair. Postscutellum velvety dark gray. Pleuron reddish brown to black; pleural tuft rather large, yellowish. Wing with hair of stem vein yellow; hair of rest of wing brownish yellow. Halter yellowish brown. Legs yellowish brown to blackish, with mostly pale yellowish hair. Claws simple. Abdomen brownish black, with yellow hair. Tergites rather large, only slightly narrower on segments 2 and 3; sternites 2 to 7 unsclerotized; sternite 8 V-shaped, with apex anterior. Anal lobe subtriangular, the anterior angle broad, the ventral angle rounded and short; cercus not much wider than long, rounded posteriorly; ovipositor short, each half a short flap with inner margin concave, distal margin rounded, not reaching base of anal lobes. Genital fork rather short and stout, the stem expanding at base and apex, the arms sclerotized, each with a weak ventral projection.

Male. Color and vestiture as in female, but basal fringe of abdomen much longer and darker. Mouthparts extremely reduced. All tergites large. Sternites 4 to 8 sclerotized. Basistyle subconical, about as long as basal width; dististyle flattened distally, about three times as long as broad, curved and tapering to a single tooth; ventral plate about as broad as long, rounded and slightly notched distally, finely pilose, with short basal arms; parameres rather small, without parameral hooks; median sclerite subrectangular, with two short, truncate, distal arms; dorsal sclerite a narrow transverse band.

Pupa. Length about 4 mm. Respiratory organ about as long as cephalothorax to apex of wing pads, consisting of 16 filaments arranged as follows: from a short base three stout branches diverge; from the dorsal of these four pairs of filaments arise at varying levels; from

the lateral and ventral branches four filaments each, one pair on a short stalk, one pair sessile. Trichomes of cephalothorax very small, slender. Tergites 3 and 4 each with eight very fine hooklets near posterior margin; sternite 5 with four larger hooklets; sternites 6 and 7 each with two, even larger. Terminal hooks dark, curved. Cocoon thin, irregular.

Larva. Mature specimens 8 mm long. Head capsule with distinct dark brown to black head spots; fulvous area around head spots lacking; median posterior group of head spots present; just anterior to these, paired mediolateral spots are present on each side; two pairs of anterolateral spots present; single anteromedian spot visible just distad of anterolateral spots; epicranial plate with dark posterolateral spots; suborbital series and single lateroventral spot present on each side. Throat cleft absent; posteroventral margin of head capsule irregular. Submentum with median trifid tooth and outermost teeth shorter than intermediate teeth; lateral margin of submentum serrate. Two long epicranial setae present on each side, appearing to arise from near lateral margins of submentum. Distance from apex of outermost tooth of submentum to anteriormost epicranial seta on same side slightly less than distance between outermost teeth. Mandible with teeth not differentiated as in *Prosimulium*, *Cnephia* or *Simulium*; with eight apical and subapical blunt teeth followed by six bristlelike teeth; inner subapical margin with three small serrations. Antenna relatively short, about one-third as long as distance from base to posterior margin of head capsule; segment length ratios base to apex, 2.4-6.4-5-1; segments 1 and 2 clear, 3 and 4 dark brown. Each cephalic fan with about 36 rays. Length of maxillary palpus slightly more than twice width at base. Pupal respiratory histoblast with 16 filaments arising from three main branches. Abdomen of preserved specimens dark mottled brown, widening posteriorly, with greatest width between segments 5 and 6. Anal cross-piece well sclerotized, lacking lightly sclerotized areas between arms; with ventral arms fused and dorsal arms separate, forming Y; dorsal arms slightly shorter than ventral arms. Anal hooks about 10 to a row in 54 rows.

Holotype. Female, Goose Bay, Labrador, August 30, 1950. J. J. Tibbles (on slide). Paratypes, 8 females, 8 males, 10 pupae, larvae, Goose Bay, Labrador, June 20 to September 6, 1950. Holotype and paratypes, Canadian National Collection; paratypes, U. S. National Museum. There is no direct association of emerged adults with pupal exuviae, but adults dissected from pupal skins agreed with the emerged adults. Larval head capsules found within the cocoons are also preserved, and these agree with the larvae collected at the type locality.

Larvae of apparently the same species have been collected at Brooktondale, Tompkins co., N. Y. April 8th and 24th, and in northern Vermont.

PROSIMULIUM ROUBAUD

Pro-Simulium Roubaud, 1906:521. Genotype *Simulium hirtipes* Fries

Prosimulium Roubaud: Smart, 1945:480-82

Generic characters. Antenna usually 11-segmented. Radial sector forked. Macrotrichia of anterior wing veins all hairlike, not mixed with spiniform ones. Anterior branch of radial sector a concave vein, bare above; posterior branch a convex vein with triple row of macrotrichia above; vein R with macrotrichia on upper side; basal cell present; Cu₂ sinuous. No calcipala, no pedisulcus. Ovipositor well developed. Respiratory organ of pupa usually with 16 or more filaments, these sometimes arising from one or more swollen structures; terminal hooks well developed. Cocoon lacking a definite shape or clearly defined anterior margin. Antenna of larva with segments 1 and 2 colorless, 3 and 4 dark brown to black; throat cleft a subrectangular notch two to three times as wide as long; median tooth of submentum trifid; inner subapical margin of submentum with 8 to 17 serrations, distalmost largest; anal cross-piece X-shaped, with ventral arms subequal to or distinctly shorter than dorsal arms; ventral tubercles lacking.

This genus is difficult to study because of the scarcity of good characters to separate a number of the species. The true identity of *Prosimulium hirtipes* is rather uncertain, but we have here applied the name to a common North American species that seems to agree with the *hirtipes* of Europe as defined by Puri, Smart and Rubzov, and as recognized in this country by Twinn. It may never be possible to determine what Fries had, but it seems best to continue the name, as it has been redefined, for this well-known species. In the references cited we have not included those of Johannsen 1903, Malloch 1914, or Dyar and Shannon 1927, since it is quite certain that they were dealing with two or more species under the name. The pupa described as having "upwards of 60 filaments" may have been *P. magnum*, although this is an excessive number for that species. It is also possible that the larva described by Puri is not the same species as the pupa he described.

It is quite possible that *P. multidentatum* Twinn occurs in New York, although we have seen no specimens we could definitely call that species. The pupa is very close to *magnum* while the female looks very much like *hirtipes* or any other of the local species except *magnum*. Positive determination can only be made if males are present in the series.

Key to Females

- 1 First flagellar segment distinctly longer than pedicel (fig. 7) ; wing usually more than 4 mm long.....*magnum* Dyar & Shannon
- First flagellar segment not conspicuously longer than pedicel; wing usually less than 4 mm long.....*hirtipes* (Fries)
rhizophorum, new species
saltus, new species

Key to Males

- 1 First flagellar segment much longer than pedicel, the scape, pedicel, and first flagellar segment about half total length of antenna (fig. 6)*magnum* Dyar & Shannon
- First flagellar segment shorter than or a little longer than pedicel; scape, pedicel and first flagellar segments combined less than half total length of antenna*hirtipes* (Fries)
rhizophorum, new species
saltus, new species

Key to Pupae

- 1 Respiratory organ consisting of one or three stout tubes or irregularly swollen structures from which arise slender filaments..... 2
- Respiratory organ consisting entirely of slender filaments arising near a common base 3
- 2 Respiratory organ consisting of one irregularly swollen club from which arise smaller swollen structures bearing one or more filaments (fig. 56)*rhizophorum*, new species
- Respiratory organ consisting of three strongly divergent and decidedly swollen trunks from which arise much more slender filaments (fig. 57)*saltus*, new species
- 3 Respiratory filaments usually 16 (fig. 64).....*hirtipes* (Fries)
- Respiratory filaments at least 20 (fig. 62).....*magnum* Dyar & Shannon

Key to Larvae

- 1 Antenna about one-third as long as distance from base to posterior margin of head capsule; teeth of submentum gradually decreasing in length from median to lateral teeth; inner subapical margin of mandible with about eight serrations, mostly large; length of maxillary palpus twice width at base*magnum* Dyar & Shannon
- Antenna about one-half as long as distance from base to posterior margin of head capsule; teeth of submentum not gradually decreasing in length from median to lateral teeth; inner subapical margin of mandible with 12 or more serrations, mostly small; length of maxillary palpus three times width at base 2
- 2 Head capsule with distinct dark brown anterolateral head spots; submentum with trifold tooth shorter than all others; intermediate teeth subequal in length to outer teeth; pupal histoblast with 16 filaments arising from three main branches; inner subapical margin of mandible with about 12 serrations.....*hirtipes* (Fries)
- Head capsule with distinct yellow anterolateral head spots; submentum with median trifold tooth larger than all other teeth; intermediate teeth shorter than outer teeth; pupal histoblast with 16 setiform filaments arising from a stumplelike base; inner subapical margin of mandible with usually about 17 serrations.....*rhizophorum*, new species

Prosimulium hirtipes (Fries)

(Figs. 2, 15, 34, 64, 90, 99, 108, 116)

Simulia hirtipes Fries, 1824:17-18, figs. 1, 2 (female, male)*Melusina hirtipes* (Fries): Lundstroem, 1911:19-20, fig. 19 (female, male)*Simulium hirtipes* Fries: Puri, 1925:350-362, fig. 20A-H (pupa, larva)*Simulium (Prosimulium) hirtipes* Fries: Twinn, 1936:103-6, fig. 1A (female, male, pupa); Smart, 1944:32, 43, 44, 48, 50, figs. 3, 8, 11a (female, male, pupa, larva)*Prosimulium hirtipes* (Fries): Rubzov, 1940:261-64, figs. 4, O, S.; 16B, 66J, 75B (female, pupa, larva); Davies, 1949:18-19 (female, male, pupa); Nicholson and Mickel, 1950:20-21, fig. 16A-E. (female, male, pupa); Sommerman, 1953:265, 268, fig. 16 (larva); Grenier, 1953:83-86, figs. 13, 18, 30, 38, 50, 86, 87, 118, 137, 138, 149, 152, 185 (male, female, larva, pupa)

Female. General color blackish brown. Wing length 3-3.75 mm. Head gray, with pale yellowish hair; frons about as wide as length of first two antennal segments, widened above. Antenna dark brown, the first two segments yellowish brown or reddish brown; first flagellar segment and pedicel about equal in size. Palpus dark, with pale yellowish hair. Mandible serrate; maxilla with retrorse teeth. Scutum brownish black, clothed with recumbent yellow hair. Scutellum with dense, erect yellow hair. Postscutellum velvety dark gray. Pleuron reddish brown to black, with some thin gray pollinosity; pleural tuft yellowish. Wing with hairs at base of costa, on stem vein, and some on under surface of subcosta, pale yellow; rest of hairs yellowish brown. Halter yellowish brown. Legs blackish brown to yellowish red; hairs yellowish except, on tarsi, brownish. Each claw with a very minute basal tooth. Abdomen brownish black, with dense yellowish hair, including the basal fringe. Tergites rather large, narrowest on segment 3; sternites 2 to 6 unsclerotized. Anal lobe L-shaped, the postero-ventral arm extending slightly beyond apex of cercus, which is about twice as wide as long and set at nearly right angles to axis of body; ventral margin of anal lobe evenly rounded; ovipositor elongate, each half tapering posteriorly, with inner margins heavily sclerotized, not reaching apex of anal lobes. Arms of genital fork each with a weakly sclerotized ventral expansion.

Male. General color as in female, but scutum and abdomen slightly darker. First flagellar segment slightly longer than pedicel. Hairs at base of costa and on stem vein dark. Halter dark. Basal fringe of abdomen long, dark brown. All tergites large, sclerotized; sternites 1, and 3 to 8 sclerotized. Basistyle stout, tapering distally, about as broad as long; dististyle about two-thirds length of basistyle, curved inward, the apex compressed, usually with three teeth, the subapical one detached from the two nearer the apex; ventral plate broad, with stout basal arms and the apex thickened and curved downward.

Pupa. Length 4.5-5.5 mm. Respiratory organ about length of dorsum of cephalothorax, usually with 16 filaments in three somewhat divergent groups; dorsal group with eight filaments arranged 3-2-3; lateral and ventral groups of four filaments each, branching dichotomously. Dorsum of cephalothorax nearly smooth; trichomes single. Tergites 4 to 8 with a single row of fine, closely set hooklets anteriorly; tergites 2 to 4 with about eight larger hooklets in a single row posteriorly, those on tergite 2 inconspicuous. Terminal hooks somewhat divergent with a short seta at base of each anteriorly. Sternite 4 with two posterior hooklets; sternites 5 to 7 each with four hooklets posteriorly, with lateral ones on sternite 5 more ventral than on sternites 6 and 7. Cocoon usually covering most of pupa.

Larva. Mature specimens 6-8 mm long. Head capsule with distinct dark brown anterolateral head spots. Throat cleft three times as broad as long. Submentum with outermost teeth slightly longer than median trifid tooth, with three intermediate teeth between median and outer on each side, subequal in length to outer teeth, and with innermost of these slightly smaller than others; lateral margins of submentum wavy but not serrate distally. Usually two long and two short epicranial setae present on each side. Mandible with small teeth having relative lengths 2-1-3 from distalmost basad; inner subapical margin of mandible with about 12 serrations, mostly small. Antenna relatively short, slightly more than half as long as distance from base to posterior margin of head capsule; segment length ratios, base to apex 6.6-9.2-9.4-1, width of first two segments approximately 0.16 their combined length. Each cephalic fan with 30 to 40 rays. Length of maxillary palpus about three times width at base. Pupal respiratory histoblast with 16 filaments arising from three main branches. Anal cross-piece well sclerotized, dorsal arms longer than ventral arms. Anal hooks 9 to 14 to a row in about 77 rows.

Distribution. Holarctic. In the Nearctic region in the Hudsonian, Canadian and Transition zones from Alaska and Labrador to California and Georgia.

New York Distribution

A common species found throughout the State.

Biology. Smart (1936, 1944) noted that the oviposition habits of *P. hirtipes* are not known but that negative information indicates that they do not lay their eggs in masses.

The appearance of larvae of this species in the fall in streams which do not flow during the summer is rather puzzling. It has been suggested

that the females drop their eggs into streams one at a time as do the females of *S. arcticum*. Since the bottoms of these streams usually remain damp throughout the summer, it is conceivable that eggs deposited in this way would remain viable. The well-developed ovipositor suggests that the eggs might be imbedded in vegetation or soil. With these points in mind, the vegetation and bottoms of Adirondack streams where *P. hirtipes* was known to be abundant were examined for eggs, but with no success.

In Amherst, Mass., on May 9, 1953, gravid females of *P. hirtipes* were collected crawling in and around a network of partially exposed fine roots which were moistened by spray from water flowing over a dam. The roots were imbedded in loose soil at the edge of a stream. Twelve days after these observations were made, the roots were pulled up and examined. Large numbers of typical black fly eggs were found loosely attached to them. These eggs averaged 0.36 mm in length and 0.159 mm in width at the widest point. The evidence that these were *P. hirtipes* eggs is as follows: Large numbers of gravid *P. hirtipes* females were collected crawling over the roots 12 days before the eggs were collected; *P. hirtipes* larvae, the only larvae collected there, were extremely numerous in this stream earlier in the season; no other black flies are known to lay their eggs in similar situations.

This species overwinters in the larval stage, usually appearing in streams in late October or November (Strickland, 1911; O'Kane, 1926; DeFoliart, 1951). *P. hirtipes* larvae collected in November and December in the Adirondacks ranged from 1 to 7 mm in length, with a modal length of about 4 mm. During the winter and early spring they make up about 80 per cent of the larval population. The number of *P. hirtipes* larvae declines rapidly during the spring. By June only a few can be found, although some may be present as late as July.

Data collected in the Adirondacks in 1950 and 1951 indicated that there might be a partial second generation of *P. hirtipes* each year. To determine the number of generations a year, all larvae of this species collected from November 1951 to July 1952 were measured. Small larvae (1-2 mm) were found as late as June 5th. There was no apparent second generation, however, as would be indicated by a sudden large increase in the number of small larvae. It seems probable that the small larvae found in April, May and June emerged from late hatching eggs laid the previous summer. This information is important to consider when planning a control program. Fall treatments made after the appearance of some *P. hirtipes* larvae would not be so effective as spring treatments because in the fall many of the black flies would be in the highly resistant egg stage. By treating the streams in the

spring after most of the eggs have hatched, a more effective control can be obtained.

In the Adirondacks *P. hirtipes* larvae pupate, for the most part, between late April and the first week in June, depending on the temperature of the stream. The peak period of adult emergence was between May 15 and May 30 in 1950, 1951 and 1952.

A comparison of data obtained by Dimond and Hart (1953) in Rhode Island with data collected in the Adirondacks also indicates that larvae pupate earlier and adults emerge sooner in warm areas than in cooler ones. Similarly, in the Adirondacks, there was a very noticeable difference in the time of pupation of *P. hirtipes* in the Old Forge area and the warmer, less elevated Forestport area.

The duration of adult life and the habits of adults, except for annoying humans, are little known. They do not begin biting for about a week after they first appear. Judging from the seasonal population changes of the different stages, the adults probably live for about three weeks.

P. hirtipes has been reported attacking man, cattle, a pony and other animals (Bromley, 1952; Davies, 1950; DeFoliart, 1951; Dimond and Hart, 1953; Dyar and Shannon, 1927; Edwards, 1915; Edwards *et al.*, 1939; Frost, 1949; Hocking and Richards, 1952; Jamnback, 1952; Jenkins, 1948; Johannsen, 1934; Malloch, 1914; Sailer, 1953; Smart, 1936, 1944; and Twinn, 1936).

Prosimulium magnum Dyar and Shannon

(Figs. 4, 6, 7, 35, 62, 83, 100, 110)

Prosimulium magnum Dyar and Shannon, 1927:6-7, figs. 1, 2, 22, 23 (female, male, pupa)

Eusimulium frisoni Dyar and Shannon, 1927:18, Pl. 1, E (female) (New synonymy)

Female. Agreeing with *P. hirtipes* (p. 23) with the following exceptions: Slightly larger, the wing length 3.25-4.5 mm. First flagellar segment of antenna decidedly larger than pedicel both in length and thickness. Tarsal claw lacking a minute basal tooth. Anal lobe L-shaped, the posterior arm curving below and beyond base of cercus, and with ventral margin evenly rounded; cercus set at an angle, with its width about three times its length; ovipositor elongate, just reaching posterior end of anal lobes; arms of genital fork with a subquadrate dorsal expansion.

Male. Agreeing with the male of *P. hirtipes* (p. 23) except as follows: First flagellar segment of antenna large and long, much longer than pedicel, so that first three antennal segments comprise

about half length of antenna. Hairs of stem vein mixed pale and dark. Basal fringe of abdomen long, dark basally, pale yellow apically.

Pupa. Agreeing with pupa of *P. hirtipes* (p. 24) except as follows: Length about 7 mm. Respiratory organ with 25 to 30 filaments, branching irregularly. Six slender hooklets on sternite 3, and four larger ones on sternite 4, in addition to those on sternites 5 to 7. Cocoon very loose and irregular, often not covering entire pupa.

Larva. Agreeing with larva of *P. hirtipes* (p. 24) except: Throat cleft about two and one-half times as wide as long. Submentum with median trifold tooth longer than all others; other teeth gradually decreasing in length from median to outermost teeth; lateral margins of submentum serrate distally. Inner subapical margin of mandible with about eight serrations, mostly large. Antenna short, about one-third as long as distance from base to posterior margin of head capsule; segment length ratios base to apex 5-7.5-8-1; width of first two segments approximately 0.19 their combined length. Each cephalic fan with about 45 fan rays. Length of maxillary palpus slightly more than twice width at base. Pupal respiratory histoblast with about 25 to 30 filaments. Abdomen with median ventral bulge often present on segment 7. Anal cross-piece well sclerotized, dorsal arms subequal in length to ventral arms. Anal hooks 15 to 16 to a row in about 92 rows.

Distribution. Transition and Upper Austral zones from Illinois and Oklahoma to Massachusetts and Georgia.

New York State Records

Fulton co.—Caroga lake (adult) May 6th (larva)

Hamilton co.—Long lake (Eaton Pond outlet), May 6th-24th (larvae and pupae)

Putnam co.—Brewster, April 24th-May 15th (adults)

Schuyler co.—Mecklenburg, June 1; Cayuta lake, April 21st (larvae), May 1st-June 1st (adults)

Tompkins co.—Ithaca, April 8th (larvae), May 22d (adults); Ringwood, May 30th (adults)

Ulster co.—Spring Glen, May 8th (adults)

Warren co.—Pack Forest Lake outlet, Warrensburg, May 8th (larvae)

Westchester co.—Armonk, May 11th; Tarrytown, May 7th (adults)

Biology. There is one generation a year of *P. magnum* in the Adirondacks. Larvae and pupae were collected at Eaton Pond outlet on May 6, 1952. Larvae were collected from a stream near the junc-

tions of Route 13 and Eastlawn Road in Ithaca, April 8, 1952, and from Pack Forest Lake outlet, Warrensburg, May 8, 1952. This species is not present in large enough numbers to be annoying in the Adirondacks. It is probably more plentiful in the lowlands.

***Prosimum rhizophorum*, new species**

(Figs. 56, 82, 109)

Prosimum sp. O'Kane, 1926:21, fig. 1 (pupa)

Female. General color yellowish brown. Wing length 3.5 mm. Head dark gray, with pale yellowish hair; frons distinctly widened above. Antenna dark brown, with scape and pedicel reddish brown; first flagellar segment scarcely longer than pedicel. Palpus yellowish brown, with pale hair. Mandible serrate; maxilla with retrorse teeth. Scutum dark brown, with recumbent pale yellow hair. Scutellum with erect yellow hair. Postscutellum reddish brown. Pleuron reddish brown; pleural tuft pale yellowish. Hairs at base of costa and on stem vein pale yellow. Halter pale yellowish. Legs yellow, the tarsi somewhat darkened. Each claw with a very minute basal tooth. Abdomen yellowish brown, with dense, pale yellowish hair; sclerotized tergites large, especially posteriorly; sternites 1 to 6 unsclerotized; sternite 7 a plate slightly wider than long, rounded anteriorly; sternite 8 larger. Anal lobe L-shaped, with dorsal arm at right angles to axis of body, and ventral arm broader, reaching nearly to apex of cercus; cercus subrectangular, about twice as wide as long; ovipositor elongate, each half with inner margin heavily sclerotized, tapering, not quite reaching apex of anal lobe; genital fork scarcely expanded anteriorly; each lateral arm with a blunt dorsal lobe.

Male. General color darker than female. Wing length 2.75 mm. Antenna dark, the first flagellar segment slightly larger than pedicel. Humerus paler than rest of scutum. Hind basitarsus about four times as long as greatest width. Sternites sclerotized. Dististyle about two-thirds length of basistyle, broad basally, flattened distally, with two distal teeth. Ventral plate broad with a median ventral lobe.

Pupa. Length 3.75-4.5 mm. Respiratory organ about one-third length of pupa, with 16 slender filaments arising from an irregularly swollen base, as shown in figure 56; four filaments arise from a basal ventral lobe, four from a more distal lateral swelling, and eight from four distal projections. Thorax smooth, with trichomes hairlike, pointing forward. Terminal hooks dark, long, slender, subparallel, without accessory hooks. Cocoon a shapeless mass.

Larva. Agreeing with the larva of *P. hirtipes* except: Head capsule with distinct, light yellow, anterolateral head spots. Submentum with median trifid tooth longer than others; with outer lateral teeth nearly as long as median; with two intermediate teeth between median and outer teeth on each side, distinctly shorter than outermost and innermost teeth; third intermediate tooth much smaller. Usually three long and one or two short epicranial setae present on each side. Inner subapical margin of mandible generally with about 17 serrations, mostly small. Antennal segment length ratios, base to apex, 8.3-11.5-10.5-1. Each cephalic fan with about 37 fan rays. Pupal respiratory histoblast with 16 short, setiform filaments arising from a stumplike base.

Holotype. Male, with pupal skin and cocoon, Waterfalls, Bear Creek Township, Luzerne co., Pennsylvania, May 13, 1948 (Goulding). **Paratypes.** CONNECTICUT: Morris, Litchfield co., April 10, 1953 (Stone), 2 pupae. ILLINOIS: Gibbins creek, Herod, May 15, 1941 (Mohr & Burks), 2 pupae; April 29, 1941 (Mohr & Burks), 1 pupal skin. MAINE: Livermore Falls, May 22, 1952 (Kusche), 1 pupa. NEW YORK: Caroga lake, April 27, 1952, 16 larvae; May 6, 1952, 2 reared males with pupal skins, 1 pupa; May 15, 1952, 6 females with pupal skins, 2 pupae (Jamnback); Brooktondale, Six Mile Creek inlet, April 24, 1952 (Jamnback), 2 pupae, and April 24, 1954 (Stone), 1 larva, 3 pupae; 11 miles N. of Lake Placid, April 24, 1954, (Jamnback), larvae and pupae. RHODE ISLAND: Kingston, May 8, 1952 (Dimond), 10 larvae, 10 pupae.

Holotype and paratypes, U. S. National Museum No. 62358. Paratypes, Illinois Natural History Survey, New York State Museum, and University of Rhode Island.

Biology. The larvae of this species are found primarily in small, temporary, rapid streams in forested areas in New York. They are often present in large numbers but the distribution is spotty. They are found with *Prosimulium hirtipes*, and *Cnephia mutata* larvae.

Prosimulium saltus, new species

(Fig. 57)

Female. No characters found to distinguish this from *P. hirtipes*.

Male. No satisfactory characters found to separate this from *hirtipes*, although there may be slight differences in the male genitalia. The ventral plate appears slightly broader in proportion to its width, and the median hirsute lobe is narrower; the dististyle is truncate, with two teeth, represented only by sockets in the single, teneral specimen.

Pupa. Length about 4.5 mm. Respiratory filaments 14 to 16 arising from three stout, divergent trunks; these trunks nearly as long as filaments; the dorsal trunk expanding distally with six to eight filaments arising from cones of varying thickness; the middle trunk, pointing forward, divides into two parts at about half its length, and each half bears two filaments; the ventral trunk divides near the apex, and each half bears two filaments, one from a stout cone and one from a slender one. Dorsum of cephalothorax nearly smooth; trichomes single. Tergites 5 to 8 each with a single row of fine, closely set hooklets anteriorly, those on tergite 5 very small; tergites 3 and 4 each with eight hooklets posteriorly. Terminal hooks somewhat divergent, with a short seta at base of each anteriorly. Sternites 4 to 7 each with four hooklets posteriorly, those on sternite 4 smaller and in two pairs, on sternites 5 to 7 larger and more evenly spaced. Cocoon small and irregular.

Larva. Unknown.

Holotype. Female with associated pupal skin, near outlet of Cayuta lake, Schuyler co., N. Y. Paratypes, one male with associated pupal skin and larval head capsule, two pupae. Holotype and one pupa collected May 17, 1950, and male and one pupa, April 24, 1954, all by the senior author from a small cascade flowing into the outlet of Cayuta lake about one mile from the lake on the east side. U. S. National Museum No. 62359. The specific name is the genitive of *saltus*, a dale, ravine or glade.

Biology. This species has been collected in one restricted locality only, at the foot of a small, temporary cascade falling off a shale cliff. The pupae were on small stones in the stream.

SUBFAMILY SIMULIINAE

CNEPHIA ENDERLEIN

Cnephia Enderlein, 1921a:199. Genotype *Simulium pecuarum* Riley Smart, 1945: 483-85

Generic characters. Antenna 11-segmented. Male holoptic. Subcosta, radius, and radial sector all close together; R_1 joining costa well beyond middle of latter's length; radial sector usually an unbranched convex vein, with a single row of hairs on upper side; vein R with macrotrichia on upper side; macrotrichia of anterior wing veins mixed hairlike and spiniform; basal cell present; submedian fold forked; Cu_2 sinuous. Legs not contrasting dark and light; fore tarsus not particularly flattened; caciapala usually small or absent; pedisulcus absent or represented by a weak constriction. Ventral plate of male

genitalia broad; dististyle more or less curved, tapering, with one or two terminal teeth.

Pupa with 8 to 30 terminal filaments in respiratory organ, often arising from a swollen knob on a short stem. Abdominal tergites 6 to 8 each with an anterior row of small spines; terminal hooks present or absent. Cocoon variable, usually irregular and poorly defined, but sometimes boot-shaped or otherwise constructed.

The larvae all have simple anal gills but are otherwise quite dissimilar.

We consider the New York State species to represent three separate subgenera, separable primarily on characters of the immature stages. These subgenera are:

Cnephia Enderlein 1921a:199. Tarsal claws of female each with a distinct tooth; calcpala small; dististyle of male with a single tooth. Respiratory filaments of pupa numerous and arising from a distinct knob on a short petiole; terminal hooks of pupa well developed; cocoon loosely woven, shapeless. Submentum of larva with small subequal teeth on each side of a slightly larger median tooth, anterior margin of submentum nearly straight; inner subapical margin of mandible with a long, thin, pointed process followed by one to three small projections and a small cleft; anal cross-piece X-shaped, with ventral arms longer than dorsal arms; ventral tubercles absent.

Ectemnia Enderlein, 1930:88. Genotype, *Cnetha taeniatifrons* Enderlein. Tarsal claws of female each with a distinct tooth; calcpala absent; a shallow pedisulcus often present; dististyle of male with two teeth. Respiratory filaments of pupa rather stout, simple, curving toward a common point; terminal hooks present; cocoon rather closely woven with the front margin ragged, attached by a woven stalk to the substratum. Submentum of larva with a deeply concave anterior margin which bears a few very small teeth; inner subapical margin of mandible smooth except for a single small serration; anal cross-piece absent; ventral tubercles present. Through the kindness of Dr Fritz Peus, the type female of *Cnetha taeniatifrons* Enderlein was sent to the senior author. Although Enderlein described *Ectemnia*, the genus that he later erected for *taeniatifrons*, as having a pedisulcus, this is shallow in the type, and not sufficiently developed to consider it as belonging to the genus *Simulium*. A considerable number of specimens in the U. S. National Museum show it to be often more weakly developed than in the type. The relationship of *C. taeniatifrons* to *C. loisae* is particularly evident in the pupal stage.

Mallochianella Vargas and Diaz, 1948a:67. Genotype, *Mallochella sibirica* Enderlein. Tarsal claws of female lacking teeth; calcpala well developed; dististyle of male with two teeth. Respiratory filaments

of pupa slender, branching irregularly; terminal hooks present; cocoon loosely woven, irregular. Submentum of larva with two broad, large, lateral teeth with a deep cleft between them from which arises a long, thin, median tooth and one or two small intermediate teeth on each side; inner subapical margin of mandible with 7 to 12 serrations, the distalmost largest; anal cross-piece as in the subgenus *Cnephia*; ventral tubercles absent. The authors of this subgenus placed it in the genus *Gigantodax* Enderlein, but we follow Rubzov, who placed both the genotype and *mutata* in the genus *Cnephia*, although in the subgenus *Stegopterna*. Both species differ from *Stegopterna* in having the tarsal claw untoothed. Following Smart's (1945) classification of the family, the two species would fall into *Cnephia* rather than *Gigantodax*.

Keys to Species of *Cnephia*

Females

- 1 Tarsal claw simple (*Mallochianella*).....*mutata* (Malloch)
- Tarsal claw with a small, distinct tooth or strong basal projection..... 2
- 2 Ninth tergite with a distinctly projecting posterior lobe with a thickened edge; claw long, the basal tooth short (*Cnephia*)
dacotensis (Dyar & Shannon)
- Ninth tergite normal, without a prominent posterior lobe; claw shorter, the basal tooth prominent (*Ectemnia*).....?*loisae*, n. sp.

Males

- 1 Dististyle with only one apical tooth.....*dacotensis* (Dyar & Shannon)
- Dististyle with two apical teeth..... 2
- 2 Hind basitarsus with a distinct calcipala.....*mutata* (Malloch)
- Hind basitarsus without a calcipala.....*loisae*, n. sp.

Pupae

- 1 Respiratory filaments more than 20.....*dacotensis* (Dyar & Shannon)
- Respiratory filaments less than 15..... 2
- 2 Respiratory filaments about 12, slender, branching irregularly from two main trunks*mutata* (Malloch)
- Respiratory filaments 8, stout, all arising from the base and curving toward a common point.....*loisae*, n. sp.

Larvae

- 1 Abdominal segment 5 projecting ventrally far beyond segment 4; head spots light; paired ventral tubercles present; throat cleft U-shaped, rounded anteriorly; submentum with concave anterior margin, with teeth very small (fig. 85).....*loisae*, n. sp.
- Abdominal segment 5 not projecting ventrally far beyond segment 4; head spots dark; paired ventral tubercles absent; throat cleft usually not rounded anteriorly; submentum not as above..... 2

- 2 Throat cleft a shallow, V-shaped notch (fig. 91); submentum with large lateral teeth, long slender median tooth, apical margin not smoothly concave (fig. 84); antenna long, nearly as long as distance from base to posterior margin of head capsule (fig. 101).....*mutata* (Malloch)
- Throat cleft U-shaped with flattened apex; submentum with small teeth, median largest anterior margin smoothly concave (fig. 86); antenna short, slightly less than half as long as distance from base to posterior margin of head capsule (fig. 103).....*dacotensis* (Dyar & Shannon)

Cnephia (Cnephia) dacotensis (Dyar and Shannon)

(Figs. 9, 14, 38, 63, 86, 103)

Eusimulium dacotense Dyar and Shannon, 1927 :20-21, figs. 48-51 (male, female); Stains and Knowlton, 1943 :268, figs. 30, 38, 39, 49, 50 (male, female); Nicholson, 1945 :281-96, figs. 1-6, 9, 10, 13, 17, 18, 21, 23, 25 (mouthparts)

Cnephia dacotense (Dyar and Shannon): Nicholson and Mickel, 1950 :22-24, figs. 17 A-E. (male, female, pupa)

Simulium (Eusimulium) lascivum Twinn, 1936 :127-30, Pl. 1, fig. 4, textfig. 8D (male, female, pupa)

Eusimulium lascivum (Twinn): Krafchick, 1943 :426-34, Pl. I, figs. A-E, Pl. II, figs. A-E (mouthparts)

Cnephia lascivum (Twinn): Davies, 1949 :19 (female, male)

Female. General color brownish black. Wing length 2.75-3.2 mm. Frons and occiput brownish black, with dark hair, the occipital area rather broad and frons distinctly diverging above. Clypeus slightly more reddish. Antenna nearly black, with scape and pedicel slightly reddened. Palpus dark. Mandible not serrate; maxilla without retrorse teeth. Scutum dark brown, subshining, with short brownish hair and three narrow paler brown lines. Scutellum usually somewhat reddened, with erect dark brown hair. Postscutellum dark, subshining. Pleuron reddish brown to nearly black; pleural tuft brown. Wing smoky, with veins yellowish brown, with all hairs brownish; subcosta and R_s with abundant hairs beneath. Halter pale yellowish. Legs almost uniformly yellowish brown, with concolorous hair; fore tibia flattened; hind basitarsus nearly six times as long as wide; calcipala very small; no distinct pedisulcus; claw rather slender, with basal swelling and small tooth. Abdomen dark brown, with basal fringe rather short, fine, yellowish to brown; ninth tergite narrowed and convex above, projecting rooflike over genitalia; sternites weakly sclerotized. Anal lobe rather elongate, the ventral margin straight, slightly produced posteriorly below, with elongate narrow projection above and concave posterior margin; cercus twice as broad as long; ovipositor small with each half triangular; arms of genital fork broad, sclerotized, each with a small dorsal tooth.

Male. Color, size and most of anatomy as in female. Hind basitarsus about four times as long as greatest width. Sternites 3 to 7

large, sclerotized. Basistyle stout, about as long as basal width, somewhat narrowed distally; dististyle about two-thirds length of basistyle, somewhat flattened, curved upward and mesally, and narrowing to apex, which bears a single short spine; ventral plate broad, rounded distally, with broad, low mesal keel ventrally, with stout, slightly converging basal arms; paramere rather small and membranous, the parameral hooks small.

Pupa. Length 4-6 mm. Respiratory organ of 30 to 40 filaments in 6 to 7 branches from a swollen base, with some further branching close to base, and additional branching more distally; total length of organ about length of thorax. Dorsum of thorax with slight transverse wrinkling; trichomes small, simple, pointing posteriorly. Terminal hooks well developed, divergent, with darkened tips. Cocoon loosely woven, shapeless.

Larva. Mature specimens 11 mm long. Head capsule with distinct brown head spots surrounded by dark fulvous area; median row which consists of about 11 irregularly placed spots without distinct isthmus between anterior and posterior groups. Throat cleft extending slightly more than one-fourth distance from posterior margin of head capsule to anterior margin of submentum; with anterior margin variable, flattened to slightly arched; widest at posterior margin. Suboesophageal ganglion colorless to light brown, never black. Submentum with six small teeth on each side of a slightly larger median tooth; with anterior margin, at most, slightly concave, lateral margins serrate distally. Usually two long and one short epicranial seta present on each side. Distance from apex of outermost tooth to anteriormost seta on same side slightly less than distance between outermost teeth. Mandible with small teeth having relative lengths 15-11-17 from distalmost basad; inner subapical margin with long thin toothlike serrations followed by one to three smaller serrations which are followed by a small cleft. Antenna short, slightly less than half as long as distance from base to posterior margin of head capsule; segment length ratios, base to apex 3.8-9-8.5-1; general color light yellow, uniform. Each cephalic fan with 41 to 49 rays. Length of maxillary palpus about two and one-half times width at base. Pupal respiratory histoblast with 30 to 40 filaments. Abdomen of preserved specimens mottled brown with light intersegmental areas; with maximum thickness at posterior margin of segment 7. Ventral tubercles lacking. Anal cross-piece well sclerotized, the area between dorsal arms lightly sclerotized; dorsal arms slightly shorter than ventral arms. Anal hooks 11 to 17 to a row in about 61 rows.

Distribution. Transition and Upper Austral zones from South Dakota and Iowa to Ontario, Rhode Island and Pennsylvania. Also one series of specimens from the Hudsonian zone at Churchill, Manitoba.

New York State Records

Herkimer co.—Lily Pad Pond outlet, May 14th (larva)

Lewis co.—Big Otter Lake outlet, May 29th (pupa), May 9th, May 29th, June 5th (larva)

Rensselaer co.—Taborton, May 9th (pupae)

Rockland co.—Bear mountain, June 1st (adult)

Schuyler co.—Cayuta Lake outlet, April 24th (larvae), May 1st-21st (adult, larva, pupa)

Tompkins co.—Ithaca, May 28th (adult)

Biology. *Cnephia dacotensis* is found only rarely in the Adirondacks. Larvae and pupae are present only in warm pond or lake outlets such as Lily Pad Pond outlet and Big Otter Lake outlet. It is found only in May and June in the larval or pupal stage, probably overwintering in the egg stage. The senior author has seen huge congregations of this species at Cayuta lake and in Pennsylvania, the adults emerging and crawling all over the stones and vegetation above water, and on one's person if he wades in among them. At the same time there may be great quantities of larvae and pupae under the surface of the water. Nicholson and Mickel (1950) reported that in Minnesota larvae are found in April and adults emerge in May, and that the species spends most of the summer and winter in the egg stage. Davies (1950) reported that the adults emerge in June in Ontario.

According to Nicholson and Mickel (1950), the pupae require about eight days to complete development. Large and apparently well-developed eggs are present in the mature pupae of the females and copulation takes place immediately after emergence. The females do not feed as adults (Krafchick, 1942; Nicholson, 1945).

Cnephia (Ectemnia) loisae, new species

(Figs. 22, 39, 65, 72, 85, 102, 111)

Female. General color dark grayish brown. Wing length 4 mm. Frons dark brown, narrow, at narrowest near middle slightly less than width of first flagellar segment, widening above and below. Clypeus gray, with pale yellow hair, about four times as wide as frons and slightly longer than wide. Antenna entirely dark brown. Mandible serrate; maxilla with retrorse teeth on both margins. Scutum dark

brown, with fine, recumbent, yellowish hairs; integument paler behind each humerus and before the prescutellar declivity, these areas connected by a slender line on each side; from the posterior paler area a very slender median line runs forward, tapering and not reaching anterior margin of scutum. Scutellum dark brown, with rather short, erect, yellowish hair. Postscutellum dark brown with grayish pollen. Pleuron brown, the upper portions somewhat reddish, the lower portion darker; pleural tuft yellowish. Wing veins dark brown; hairs of stem vein yellow brown; subcosta with hairs beneath; basal cell very small. Halter pale yellow, with stem darker. Legs almost uniformly dark brown; hind basitarsus about 5 times as long as wide; calcipala absent; no pedisulcus; each claw strongly curved, with a strong basal projection nearly two-thirds length of claw. Abdomen dark brown, the membranous areas paler; tergites large, narrowest on segments 4 and 5; subshining, with pale yellow hair; basal fringe pale yellow; sternites 2 to 7 unsclerotized; sternite 8 rather large, rounded anteriorly. Anal lobe subquadrate, the anteroventral portion paler, with a very short ventral projection at corner; cercus slightly longer than broad, rounded and slightly tapering posteriorly; ninth sternite broad, heavily sclerotized; ovipositor with inner margins of the two halves parallel, basally sclerotized and apically pale, rounded, little produced; genital fork not expanded at base; arms short, broadly expanded apically, each with a broad ventral lobe and a short, acute, subapical dorsal projection.

Male. Slightly darker than female. Wing length 3.5 mm. Hairs of clypeus brownish. First flagellar segment about 1.6 times as long as second flagellar segment. Mandible apparently without serrations; maxilla reduced, without teeth. Hairs of thorax mixed pale yellow and brownish. Hairs of stem vein brown; subcosta without hairs beneath. Halter slightly darker than in female. Hind basitarsus about 3.4 times as long as wide. Basal fringe and most abdominal hairs dark brown; sternites 3 to 8 sclerotized. Basistyle subquadrate; dististyle about 4.5 times as long as basistyle, curved and apically compressed; apex with two small teeth; ventral plate more than twice as broad as long, the basal arms flattened and divergent, the center with a rather narrow, ventrally curved lip; hairs on ventral plate short and inconspicuous; median sclerite about as wide at base as lip of ventral plate, slightly narrowed distally and dividing into a pair of slightly divergent prongs; paramere of moderate size, the arm without hooks.

Pupa. Length about 4 mm. Respiratory organ about one-third length of pupa, of eight moderately stout, slightly tapering filaments, all arising near the base, curving and converging to a common point

on an extension of the median axis of the body. Dorsum of cephalothorax nearly smooth, the trichomes moderately developed, straight, single. Tergite 2 with six posterior hooklets, the two lateral ones on each side close together; tergites 3 and 4 each with eight hooklets posteriorly; tergite 5 with six posterior hooklets; tergites 7 and 8 each with an anterior row of fine, closely set hooklets. Terminal hooks small, divergent. Sternites 6 to 8 each with four hooklets posteriorly. Cocoon consisting of a slender woven cylinder filled with debris and attached to the substratum by a slightly enlarged base, on which, about half way out, is a closely woven, wall-vase-shaped container for the pupa, with the anterior margin ragged.

Larva. Mature specimens 7.5 mm long. Head capsule with distinct yellow to white head spots, with dark fulvous area around head spots; anterior median group separated from posterior median group by wide dark brown isthmus; posterolateral spots obscure. Throat cleft U-shaped, rounded apically, slightly narrowed posteriorly, extending about one-third distance from posterior margin of head capsule to teeth of submentum. Suboesophageal ganglion light except near anterior margin where tinged with black. Submentum with deeply concave anterior margin, with small median tooth, two small intermediate teeth and a single large outer tooth on each side; lateral margins wavy but not serrate distally. Usually three long epicranial setae on each side. Distance from apex of outermost tooth of submentum to anteriormost seta on same side one-fourth distance between outermost teeth. Mandible with small teeth broader and more heavily pigmented than in other species, having relative lengths 13-11-9; inner subapical margin smooth except for single small serration. Antenna long, almost as long as distance from base to posterior margin of head capsule; segment length ratios base to apex 11.4-16.8-3.6-1; segment 1 clear ventrally, pigmented yellow dorsally, segment 2 mostly clear, yellow dorsally near base, segments 3 and 4 light yellow. Each cephalic fan with 68 rays. Length of maxillary palpus slightly less than four times width at base. Pupal respiratory histoblast with eight filaments. Abdomen of preserved specimens mottled brown with light intersegmental areas; segment 5 projecting abruptly ventrally about one-fourth width of preceding segment; following segments tapering posteriorly. Ventral tubercles present, directed posteriorly anal cross-piece absent or not sclerotized. Anal hooks 7 to 8 to a row in about 69 rows.

Holotype. Male, Pine creek, Forestport, N. Y., April 10, 1952 (H. A. Jamnback). Paratypes, 1952, same locality, April 4th, male, 2 pupal skins, 8 pupae; April 10th, 3 females, 2 pupal skins; April 17th,

male with pupal skin; Gulf creek, May 1st, female; 1954; White Lake outlet, Bear creek, March 31st, larvae; Pine creek, April 7th, pupae; Long Lake outlet, April 20th, pupae; Little Woodhull R., April 24th, in car, female (all Jamnback). Holotype, U. S. Nat. Mus. No. 62360; Paratypes, U. S. National Museum and New York State Museum.

Biology. This species has only been found in the vicinity of Forestport, N. Y. Larvae and pupae were found in late March and early April. It has been collected only in streams 20 to 30 feet wide where the bottom is sandy and large rocks are present. The larvae and pupae have been found almost exclusively on the large rocks at depths of one to two feet. *C. loisae* probably overwinters in the larval stage with adults emerging in the early spring. There is apparently only one generation a year.

The name *Simulium invenustum* Walker has been associated with both *Cnephia pecuaria* (Riley) and *Cnephia taeniatifrons* (Enderlein). Notes on the types of *invenustum* provided by Paul Freeman of the British Museum rather clearly indicate that neither *pecuaria* nor *taeniatifrons* is *invenustum*, and the type locality (St Martin's Falls, Albany river, Hudson's bay) is also against such synonymy. There is the possibility that what we here describe as new is *Cnephia invenusta*, but we prefer not to so determine it without further evidence.

We take pleasure in dedicating this species to the wife of the junior author.

***Cnephia* (Mallochianella) mutata (Malloch)**

(Figs. 5, 16, 36, 54, 80, 84, 91, 101)

Prosimulium mutatum Malloch, 1914:20-21, pl. 2, fig. 18 (female)

Eusimulium mutatum (Malloch): Dyar and Shannon, 1927:17, figs. 34, 35 (female)

Mallochella mutata (Malloch): Enderlein, 1930:91

Simulium (*Eusimulium*) *mutatum* (Malloch): Twinn, 1936:125-27, fig. 8C (female, male, pupa, larva)

Cnephia mutatum (Malloch): Davies, 1949:19 (pupa); Nicholson and Mickel, 1950:25-26, fig. 18A-E (female, male, pupa)

Eusimulium mutatum permutatum Dyar and Shannon, 1927:17-18, fig. 36 (female)

Undescribed species No. 2, Ritcher, 1931:243-45, pl. 6, figs. 1-6 (pupa, larva)

Female. General color grayish black. Wing length 3-3.5 mm. Frons dark grayish, pollinose, divergent above, at narrowest slightly narrower than concolorous clypeus; both with yellowish hairs. Antenna entirely blackish, with pale pubescence. Palpus blackish; sensory organ of third segment about one-third length of segment. Mandible serrate; maxilla with retrorse teeth. Scutum dark brownish gray, subshining, clothed with short, pale yellow, recumbent hairs. Humerus often more or less reddened. Scutellum concolorous with scutum, with erect dark

and more recumbent pale hairs. Postscutellum velvety gray. Pleuron grayish black, with portion posterior to sternopleuron usually reddish or yellowish brown; pleural tuft pale yellow. Wing veins yellow to yellow brown, with hairs and spinules black to dark brown, a few at base of costa yellowish; hairs of subcosta and radial sector on under surface abundant. Halter yellow to brownish. Legs almost uniformly yellow-brown with yellow hair; fore tibia flattened; hind basitarsus about 6-7.5 times as long as wide, nearly parallel-sided; calcipala broadly rounded, extending about one-third length of second tarsal segment; no distinct pedisulcus; claws simple. Abdomen brown, the basal fringe long, yellow; sternites not sclerotized. Anal lobe narrow dorsally, expanded ventrally, extending under cercus, expanded portion notched posteriorly; cercus twice as long as broad, subquadrate with rounded posterior angles; ovipositor with each half rounded posteriorly, not produced; arms of genital fork broadly flattened distally, pale.

Male. Somewhat darker than female. Scutum dark, in some lights showing a pair of black submedian stripes, in others a very slender median pale stripe and a pair of pale comma-shaped marks from inner angles of humeri. Pleural tuft, halter, and hairs of abdomen darker than in female. Legs darker, the hind basitarsus distinctly broader than in female, about three times as long as broad; calcipala less produced. Hind margins of tergites narrowly paler; sternites large, sclerotized. Basistyle small, subquadrate; dististyle short, about two-thirds length of basistyle, triangular, the apex with two small teeth; ventral plate broad, with short, flattened, slightly divergent basal arms; distal portion with a broad rounded lip; paramere very small, arm with fine hairs but no distinct hooks; median sclerite Y-shaped, the base slender, the arms nearly as long as base.

Pupa. Length 3-4 mm. Respiratory organ subequal in length to pupa; normally with 12 filaments; the main trunk divides near base into two main branches; the upper branch divides again, one subbranch with four divisions, the other with three; the lower main branch divides into two subbranches, one with three divisions, the other with two. Dorsum of thorax smooth, the trichomes rather large. Terminal hooks of abdomen large. Cocoon poorly defined, of loosely woven silk.

Larva. Mature specimens 6 mm long. Head capsule with distinct dark brown head spots, lacking dark fulvous area around head spots; with about five anterior and four posterior median head spots, these groups widely separated by a yellow isthmus; with single lateral spot on each side of ventral surface of head capsule slightly anterior

to anterior margin of throat cleft. Throat cleft a small, V-shaped notch extending less than one-fifth distance from posterior margin of head capsule to tip of longest submental tooth. Suboesophageal ganglion never a distinct black, but occasionally brownish. Submentum with nine teeth (excluding processes beyond two large lateral teeth); the outermost teeth large and broad, with small tooth on inner slope of each side, one or two additional small teeth present on each side of long narrow median tooth, which is shorter than large lateral teeth; lateral margins medially wavy, with distal serrations. Two to three long epicranial setae and a variable number of short setae present on each side. Distance from apex of outermost tooth of submentum to anteriormost seta on same side slightly greater than distance between outermost teeth. Mandible with small teeth having relative lengths 8-5-15 from distalmost basad, with teeth 1 and 2 almost obscured by apical teeth; inner subapical margin with 7 to 12 serrations, distal ones larger than basal. Antenna long, slightly longer than distance from base to posterior margin of head capsule; segment length ratios, base to apex 10.4-9.6-8-1, yellowish with pigmentation somewhat heavier on dorsal surface, with segments 3 and 4 darker than segments 1 and 2. Each cephalic fan with about 54 rays. Length of maxillary palpus slightly more than three times width at base. Pupal respiratory histoblast with 12 filaments arising from two main branches. Abdomen of preserved specimens with brownish and yellowish areas, with light intersegmental areas; median ventral bulge, on segment 8. Anal cross-piece well sclerotized, area between arms not sclerotized; ventral arms longer than dorsal arms. Anal hooks 11 to 13 per row in about 60 rows.

Distribution. Canadian, Transition and Upper Austral zones from Alaska and Labrador to California, Wyoming, Arkansas and Alabama.

New York State Distribution

Moderately abundant throughout State. An early spring species.

Biology. The larvae of *C. mutata* are found in temporary or permanent streams. They are most numerous in streams with sandy bottoms, with few rocks and pebbles, and with abundant trailing grass. This species overwinters in the larval stage in the Adirondacks and probably in the rest of New York State. In November and December it makes up about 20 per cent of the total larval population. This percentage remains relatively constant until about March, when it begins to decline owing to pupation and appearance of larvae of other species. Larvae may be found until late May or early June. Adults have been

collected from rocks or grass on stream edges in May. Data collected in the Adirondacks support Davies' (1950) statement that there is one generation per year. The adults are usually not anthropophilic, at least in the central Adirondacks. They have been caught in collections of annoying adults in the Forestport area and by the Bozenkill near Delanson, Davies (1950), Hocking and Richards (1952), and Frohne and Sleeper (1951) report that this species is rarely annoying to man.

SIMULIUM LATREILLE

Simulium Latreille, 1802:426. Type *Rhagio colombaschensis* Fabricius.

Generic characters. Radial sector unbranched; macrotrichia of anterior wing veins mixed hairlike and spiniform; vein R usually without macrotrichia on upper side; basal cell absent; Cu_2 sinuous; calcipala usually well developed; pedisulcus well developed; antenna with 11 segments; ovipositor not greatly produced. Abdomen of pupa with terminal hooks very small or absent; cocoon well developed with a distinct anterior margin, but not on a stalk. Larval submentum with nine teeth, with the outermost and median largest and usually subequal, the three intermediate teeth on each side much smaller, the outermost of these slightly larger than the others; anal cross-piece X-shaped, with well sclerotized ventral arms, subequal to or distinctly longer than dorsal arms.

We recognize, in the New York State fauna, three of the subgenera of this genus. These are:

Eusimulium Roubaud, 1906:521. Genotype, *Simulium aureum* Fries. Vein R with hairs above. Respiratory organ of pupa with three to ten filaments; cocoon simple, wall-vase-shaped, with or without a median anterior projection. Larva of *aureum* with mandibles having the inner subapical margin with a double or two single toothlike processes, with the anterior portion twice as long as posterior; other species with a single large toothlike process projecting at right angles from margin, followed by two to four small, anteriorly pointing projections; anal gill of all except *aureum*, compound with well-developed accessory lobes; ventral tubercles well developed.

Neosimulium Rubzov 1940:116, 124, 130. Genotype, *Simulium vittatum* Zetterstedt. Legs markedly bicolored; calcipala small; pedisulcus near middle of second hind tarsal segment; abdomen of female with a distinct pattern of black and light gray; male dististyle with two to four terminal teeth. Respiratory organ of pupa with 10 to 24 filaments; trichomes of cephalothorax well developed; abdominal sternites 6 and 7 with four spines each; cocoon simple, wall-vase-

- 2 Postcutellum with appressed yellow scales; ventral plate and dististyle as in figure 30.....*aureum* Fries
- Postscutellum without scales; ventral plate and dististyle quite different.....*gouldingi* Stone
latipes (Meigen)
pugetense Dyar & Shannon
- 3 Dististyle short and stout with three or more teeth (*Neosimulium*).....*vittatum* Zetterstedt
- Dististyle longer, with only one or two teeth, or no teeth (*Simulium*)..... 4
- 4 Dististyle with a distinct basal, internal tubercle bearing stout spines.....*tuberosum* (Lundstroem)
- Dististyle without a distinct tubercle at base..... 5
- 5 Ventral plate more or less compressed, with denticles on margin..... 6
- Ventral plate triangular or broadly rounded, without denticles on margin.. 11
- 6 Basal arm of ventral plate without lateral projections; posterior fourth or less of scutum shiny, clothed with strong erect hairs..... 7
- Basal arms of ventral plate with distinct lateral projections; posterior third of scutum shiny and with hairs indistinct..... 10
- 7 Ventral plate very compressed, in the shape of an inverted Y; with ventral process or keel..... 8
- Ventral plate broader, tooth-shaped, without ventral process, or this not very prominent 9
- 8 Ventral keel of ventral plate setose, forming an angle before apex of median portion of ventral plate.....*decorum* Walker
- Ventral keel of ventral plate concave in profile, the angle being at apex.....*corbis* Twinn
- 9 Toothed lateral margins of ventral plate flaring outward, when viewed on end appearing somewhat trilobed, the two lateral lobes with teeth.....*venustum* Say
- Toothed lateral margins turned inward toward each other concealing the central region and the distoventral lobe narrower.....*verecundum*, n. sp.
- 10 Velvety black area of mesoscutum less extensive, the distance separating the apex of the iridescent anterior spot from the prescutal shiny area much less than the distance from the hind margin of the black area to the scutellum; white spot at base of hind tibia about one-third length of tibia.....*fibrinflatum* Twinn
- Velvety black area more extensive, the distances described above subequal; white of hind tibia about one-fifth length of tibia.....*jenningsi* Malloch
- 11 Ventral plate with a broad median notch nearly dividing it into two parts.....*pictipes* Hagen
- Ventral plate without a broad median notch.....*parnassum* Malloch

Key to Pupae

- 1 Respiratory filaments 4, or if more, the anterior margin of cocoon with a long median projection (*Eusimulium*)..... 2
- Respiratory filaments 6 or more; anterior margin of cocoon without a long median projection 6
- 2 Respiratory filaments 4 3
- Respiratory filaments 6 or 8 (anterior margin of cocoon with long median projection) 5

- 4 Throat cleft narrowly V-shaped, extending one-third distance from posterior margin of head capsule to teeth of submentum... *parnassum* Malloch
- Throat cleft bulbous, width and depth near middle subequal, extending one-half distance from posterior margin of head capsule to teeth of submentum 5
- 5 Abdomen light to yellowish brown; suboesophageal ganglion light; pupal histoblast with 10 slender filaments..... *jenningsi* Malloch
- Abdomen blackish brown; suboesophageal ganglion faintly dark; pupal histoblast with 6 stout filaments..... *fibrinflatum* Twinn
- 6 Infuscation around head spots not extending beyond inner edge of anterolateral spots; light yellow area present just anterior to apex of throat cleft on epicranial plate; anal cross-piece narrowly fused medially; mature specimens 8-10 mm long..... *decorum* Walker
- Infuscation around head spots extending to outer edge of anterolateral spots; light yellow area absent on epicranial plate just anterior to apex of throat cleft; anal cross-piece broadly fused medially; mature specimens 6-7 mm long..... *venustum* Say
verecundum, n. sp.
- 7 Throat cleft a bowed-V; mature larvae 5.5-7 mm long; anal hooks 11 to 15 per row..... 8
- Throat cleft not as above; antenna with light spot on venter of second segment (on distal half); mature larvae 9-11 mm long; anal hooks 18 to 27 per row..... 9
- 8 Mature larvae 7 mm long; throat cleft extending two-thirds distance from posterior margin of head capsule to teeth of submentum, with narrow apical extension; suboesophageal ganglion light, epidermis in throat cleft black..... *corbis* Twinn
- Mature larvae 5.5 mm long; throat cleft extending less than one-half distance from posterior margin of head capsule to teeth of submentum, lacking narrow apical extension (fig. 93); suboesophageal ganglion distinctly black, epidermis in throat cleft usually light. *tuberosum* (Lundstroem)
- 9 Submentum with large median tooth extending far beyond lateral teeth; second antennal segment with bilobed ventral light spot; anal gill with three lobes bearing numerous large ventral accessory lobes; throat cleft extending half way from posterior margin of head capsule to apex of submentum; anal hooks in 127 to 135 rows..... *pictipes* Hagen
- Submentum not with large median tooth extending far beyond lateral teeth; second antennal segment with single lobed ventral light spot; anal gill with three lobes; small ventral accessory lobes usually visible; throat cleft extending slightly more than one-fourth distance from posterior margin to apex of submentum; and hooks in 67 to 88 rows
..... *vittatum* Zetterstedt
- 10 Throat cleft more or less flattened on anterior margin; anal gill with three simple lobes; inner subapical margin of mandible with two serrations, anterior one twice as long as posterior; respiratory histoblast with four filaments..... *aurcum* Fries
- Throat cleft rounded on anterior margin; anal gill made up of three compound lobes; inner subapical margin of mandible with five serrations typically; large anterior serration more or less flat on anterior margin and forming an angle of about 90° with margin, followed by two to four small, anteriorly pointing serrations; respiratory histoblast with four or six filaments 11
- 11 Second antennal segment slightly longer than third segment; respiratory histoblast with six filaments..... *gouldingi* Stone
- Second antennal segment more than twice as long as third segment; respiratory histoblast with four filaments..... 12

- 12 Larvae present in streams in early spring (March in Adirondacks); four long and one to two short epicranial setae on each side.....*pugetense* Dyar & Shannon
- Larvae present in streams in late spring and summer (May and June in Adirondacks); one to three long and one to two short epicranial setae on each side.....*latipes* (Meigen)

Simulium (Eusimulium) aureum Fries

(Figs. 30, 45, 66, 96)

- Simulia aurea* Fries, 1824:16 (male, female)
- Melusina aurea* (Fries): Lundstroem, 1911:22, figs. 3, 23, 24 (male)
- Simulium aureum* Fries: Edwards, 1915:39-40 (female only); Edwards, 1920:242-44, figs. 1k, 4m (pupa, larva); Puri, 1925:354-56, fig. 17 (pupa, larva); Nicholson and Mickel, 1950:37-40, fig. 25 (male, female, pupa); Grenier, 1953:108-9, figs. 33, 67, 77, 106, 176 (female, male, pupa, larva)
- Nevermannia auroa* (Fries): Enderlein, 1921a:199
- Cnetha auroa* (Fries): Enderlein, 1922:69 (misspelling)
- Eusimulium aureum* (Fries): Dyar and Shannon, 1927:14, fig. 44 (female); Hearle, 1932:9 (female, pupa); Stains and Knowlton, 1943:266, figs. 31-33, 60, 61 (male, female)
- Simulium (Eusimulium) aureum* Fries: Twinn, 1936:115-17, fig. 6A (male, female, pupa); Smart, 1944:36, 43, figs. 11g, 13m, 17k (male, pupa, larva); Vargas, Martinez and Diaz, 1946:166; Sommerman, 1953:271, 273, fig. 34 (larva)
- Simulium bracteatum* Coquillett, 1898:69 (male, female); Johannsen, 1903:358-59, pl. 38, figs. 13, 15 (female, male); Strickland, 1913:45-46, pl. 1, figs. 1-9 (pupa, larva); Malloch, 1914:38-39 (female, male); Jobbins-Pomeroy, 1916:5, text figs. 3, 4, 6, pl. 2, fig. 4, pl. 3, fig. 7, pl. 4, fig. 7, pl. 5, fig. 3 (male, pupa, larva)
- Eusimulium aureum bracteatum* (Coquillett): Dyar and Shannon, 1927:14, figs. 24-26 (female, male)
- Eusimulium bracteatum* (Coquillett): Johannsen, 1934:60 (larva)
- Simulium angustipes* Edwards, 1915:40, figs. 1j, k, l, 4h (male); Friederichs, 1921:55, fig. 21c (female, male)
- ?*Simulium obtusum* Dyar and Shannon, 1927:15 (lectoparatype male: see Stone, 1949:138)
- Eusimulium pilosum* Knowlton and Rowe, 1934a:580, figs. 1-2 (female)
- Simulium (Eusimulium) pilosum* Knowlton and Rowe: Twinn, 1938-49 (female)
- Eusimulium utahense* Knowlton and Rowe, 1934a:582, figs. 5-6 (female)
- Simulium (Eusimulium) donovani* Vargas, 1943:359-60, pl. 5, figs. 34-36 (female)
- Simulium diazi* De Leon, 1945:5, fig. 7 (pupa)

Female. Generally dark grayish brown, covered with glistening, pale to golden yellow, fine hairs. Wing length 2.75-3 mm. Frons gray, with recumbent hairs; width at narrowest about half width of clypeus, strongly divergent above; clypeus about as long as wide, gray, with nearly white hairs. Antennal scape and pedicel yellowish, the flagellum darker. Palpus dark brown. Scutum brown, rather uniformly covered with recumbent yellow hairs. Humerus yellow. Scutellum with abundant pale yellow hairs, both erect and recumbent. Postscutellum reddish to dark brown, centrally with a single or divided patch of appressed yellow hairs. Pleuron grayish brown, the pleural tuft dense, yellow. Wing veins yellow brown, the long hairs at base of costa and

on stem vein pale yellow, the other hairs and spinules darker; vein R with short hairs above; subcosta with hairs beneath. Halter pale yellow, with base darker. Legs yellow, with pale yellow hair except for dark brown at apices of femora, tibiae and entire tarsi except for most of hind basitarsus; outer surface of fore tibia distinctly white; fore basitarsus nearly cylindrical; calcipala and pedisulcus distinct; hind basitarsus about five times as long as greatest width; claws each with stout basal tooth. Abdomen dark brown with pale yellow to silvery white hairs, the tergites small, gradually widening posteriorly, subshining; sternites not sclerotized. Anal lobe subtriangular, narrow above, widened anteriorly and posteriorly below, with anterior and posterior margins concave, anterior portion not extending as far ventrally as posteriorly; cercus twice as broad as long, rounded subquadrate; ovipositor short, with apices of the two lobes slightly divergent; arms of genital rod acute distally, with a slender sclerotized dorsal tooth and a broader, less sclerotized ventral lobe.

Male. Darker than female, with pale hairs more golden. Slightly smaller. Scutum dark brown, with golden-yellow hairs dense obliquely behind humeri, laterally and posteriorly, with hairs centrally orange brown, somewhat shorter. Scutellum with yellow or brownish erect and recumbent hairs. Appressed golden hairs on postscutellum as in female. Pleural tuft yellow. Hairs at base of costa and on stem vein mostly dark brown. Halter yellow. Dark of legs considerably more extensive; fore tibia mostly white on outer surface; hind tibia pale on basal third; hind tarsus about as in female. Abdomen velvety black to reddish brown; hairs usually dark brown, sometimes mixed with golden hairs in the basal fringe and laterally on the posterior segments; tergites larger than in female; sternites sclerotized. Basistyle about as long as broad, somewhat conical; dististyle very short, about one-third length of basistyle, with outer margin convex, the inner margin nearly straight, with strong tooth at apex; ventral plate with a narrow triangular central portion and widely divergent basal arms, their apices broad, truncate; each paramere with a single hook.

Pupa. Length about 4 mm. Respiratory organ about three-fourths length of pupa, of four slender filaments; upper pair with a short petiole and the two filaments widely divergent; lower pair with almost no petiole and less divergent. Dorsum of thorax smooth; trichomes distinct, curved. Terminal hooks very short. Cocoon simple, wall-vase-shaped, tightly woven, the anterior margin oblique with a distinctly thickened rim and no anterior projection.

Larva. Mature specimens 7 mm long. Head capsule with dark head spots; fulvous area very light or absent; isthmus narrow between anterior and posterior median groups; epicranial plate fumeous brown, lacking ventrolateral spots. Throat cleft U-shaped; width and length subequal; apex flat or slightly upcurved medially; lateral margins subparallel, diverging slightly from posterior to anterior. Suboesophageal ganglion never distinctly black. Submentum typical; lateral margins serrate distally, with distalmost serration large and pigmented. Usually three long and one to two short epicranial setae present on each side. Distance from apex of outermost tooth of submentum to anteriormost epicranial seta on same side subequal to distance between outermost teeth. Mandible with small teeth having relative lengths of 14-11-13 from distalmost basad; inner subapical margin with two simple teeth, anterior tooth one to two times as long as posterior. Antenna about three-fourths as long as distance from base to posterior margin of head capsule; segment length ratios, base to apex: 10.3-11.7-6.5-1; uniformly yellow except segment 1 slightly darker than others. Each cephalic fan with about 45 rays. Length of maxillary palpus slightly more than three times width at base. Pupal respiratory histoblast with four filaments. Abdomen of preserved specimens mottled brown, with light intersegmental areas. Ventral tubercles conspicuous. Anal gill made up of three simple lobes. Anal cross-piece well sclerotized, areas between arms lightly sclerotized; ventral arms slightly longer than dorsal arms. Anal hooks about 11 to a row, in about 60 rows.

Distribution. Holarctic; in the Nearctic region from Alaska and Maine to Guatemala.

New York State Records

Franklin co.—Tupper Lake, May 29th (larva)

Hamilton co.—Salmon river, July 31st, August 25th (larva)

Herkimer co.—Bald Mountain Pond outlet, June 16th-August 19th (pupa); same, June 16th-August 23d (larva)

Oneida co.—Forestport area, June 16th-August 20th (larva)

Tompkins co.—Brooktondale, April 24th (larva); Ithaca, May 12th, June (adult)

Biology. The eggs of *S. aureum* are 0.21-0.26 mm in length (DeFoliart, 1951). They are laid on trailing grass or leaves and deposited in a compact mass, one layer deep, all the eggs standing on end and covered by a thick layer of gelatinous material (DeFoliart, 1951).

The incubation period of the eggs is 8 to 12 days, according to Malloch (1914). The larval period is said to be 4 to 5 weeks (Puri, 1925). The larvae are found in warm streams in the Adirondacks, especially at lake outlets such as Bald Mountain Pond outlet near Old Forge. They are somewhat more generally distributed in the warm meadow streams in the less elevated Forestport area. Jenkins (1948) reported that this species is found in warm, slow-moving lake outlets in Alaska. Jobbins-Pomeroy reported five to six generations a year in South Carolina. Pacaud (1942) in Europe, Edwards (1920) in the British Isles, Davies (1950) in Ontario, and Forbes (1912) in Illinois, all reported two generations a year, and this appears to be the case in New York State.

This species is not a pest in the Adirondacks. Edwards (1920) and Cameron (1922, as *bracteatum*) reported that there is no evidence of blood-sucking in this species. It has been reported attacking goslings (Smart 1944; Bequaert 1938). Hocking and Richards (1952) state that this species is rarely annoying.

***Simulium (Eusimulium) croxtoni* Nicholson and Mickel**

(Fig. 50)

Simulium croxtoni Nicholson and Mickel, 1950:41-42, fig. 20, A, B

Eusimulium croxtoni (Nicholson and Mickel) : Hocking and Richards, 1952:240

Since we have only a single female dissected from a pupa, and two additional pupal skins and cocoons, we here reproduce the original description.

"Female. Length about 2 millimeters. Vertex as broad as the clypeus, narrow above the antennae, light gray pollinose, moderate to densely covered with white hair-like setae. Clypeus bluish-gray pollinose, longer than broad, moderately white setose. Antennae 11-segmented, dark brown with the basal two segments very slightly paler on some specimens. Palpi dark brown. Mesonotum dark brown to black, somewhat gray pollinose; moderately covered by hair-like setae, those on the margins white, while those on the disk are brassy yellow. (On paratype specimens the pile is entirely white.) Scutellum dark brown with upright and recumbent pale setae. Postnotum dark brown, shining pollinose. Pleural area bluish-gray pollinose; membranous areas brown; tuft white. Halteres pale; bases dusky, setose. Wings clear; hair-like setae on the costa between the humeral cross vein and the base of the wing white ventrally and dark dorsally; those on the vein long and rusty brown in color; setae on other veins dark; subcosta with a row of setae ventrally; radius setose dorsally on its entire length. Legs mostly brown; front coxae gray pollinose, coxae, femora and tibiae densely covered by white setae; tarsi black, dark setose; calcipala and pedisulcus present; claws with large basal and sub-basal teeth, the sub-basal tooth being the longer. Abdomen with the basal scale pale dorsally; fringe long and white; remaining seg-

ments dark brown, subopaque; pilosity hair-like, most dense laterally and terminally; white except on the terminal segments where a few dark setae may be found.

"Genitalia: Ovipositor valves short and membranous, darkened at the inner margins. Anal lobe broader than long, narrow dorsally, expanded mesally; the antero-ventral margin produced as a broad lobe; the postero-ventral margin indented; setose on the posterior half. Cercus broadly rounded. Stem of the genital rod sclerotized; crotch with an indentation caused by mesal expansions of the bases of the arms; arms membranous, gradually expanded at the tips, the ventral margins sclerotized narrowly; a small tooth present about midway from the crotch to the tip of the arms."

Male. Unknown.

"Pupa. Respiratory filaments of about equal length and thickness, and approximately five-eighths the length of the pupa. Each tuft with eight filaments arising from a short trunk as follows: a pair of filaments arising from a short-stemmed dorsal branch; a shorter stalked lateral branch which produces a single filament ventrally near its base and a relatively long-stemmed dorsal pair; and a ventral branch which divides into a single dorsal filament and a short-stemmed ventral pair. The stem of the main lateral branch is about one-half the length of that of the main dorsal branch which is, in turn, about one-half the length of the stem of the main ventral branch.

"The cocoon is of the wall vase type and is rather loosely woven. The anterior margin is thickened and protruded dorso-medially as a short, flat projection similar to that which occurs on the cocoons of *S. latipes* Meigen."

Larva. Unknown.

Distribution. Hudsonian and Canadian zones from Labrador to northern Minnesota and New York.

New York State Records

Oneida co.—Cassville, May 28, 1952 (pupal skin and cocoon); Forestport, June 16, 1952 (pupa)

Simulium (*Eusimulium*) *gouldingi* Stone

(Figs. 60, 75, 106)

Simulium (*Eusimulium*) *gouldingi* Stone, 1952:90-91 (female, male, pupa); Sommerman, 1953:271, 272, fig. 30 (larva)

Female. General color grayish brown, with yellow brown to gray hairs. Wing length 2.75 mm. Frons and clypeus gray, with fine, recumbent gray hairs; width of frons at narrowest about half width of clypeus, strongly divergent above. Antenna with scape and pedicel reddish brown, flagellum dark, with fine gray pubescence. Palpus nearly black. Scutum brown, with a covering of fine yellow brown,

recumbent hairs, both integument and hairs grayer around the entire margin. Humerus reddish. Scutellum reddish brown, with both erect and recumbent yellow brown hairs. Postscutellum dark, velvety gray. Pleuron grayish brown, pleural tuft yellowish gray. Wing veins brown, the long hairs at base of costa pale yellow, those on stem vein brownish black; subcosta with hairs beneath. Halter pale yellow. Legs mostly yellow brown, coxae and apices of femora and tibiae, and tarsi except most of hind basitarsus darkened; outer surface of fore tibia rather distinctly whitened; fore basitarsus nearly cylindrical; calcipala and pedisulcus distinct; hind basitarsus slightly more than five times as long as greatest width; claw with a stout basal tooth. Abdomen reddish brown, with pale yellow hairs, the tergites gradually widening posteriorly, subshining; sternites not sclerotized. Anal lobe somewhat widened below, the ventral margin not produced; cercus slightly wider than long, tapering slightly posteriorly; ovipositor short, blunt, pale posteriorly; arms of genital fork irregularly widened, weakly sclerotized.

Male. Darker than female, with pale hairs entirely golden yellow. Wing length 2.25-2.6 mm. Scutum dark brown, with hairs golden, somewhat darker on disk. Humerus and scutellum paler, the latter with erect brown and recumbent golden hairs. Pleuron mostly reddish black; pleural tuft nearly black. Hairs of wing all black. Halter yellowish brown, the stem darker. Legs blackish brown, the fore coxae, femora, and tibiae yellowish, with yellow hair; hairs elsewhere mostly dark; hind tibia slightly swollen, about 4.75 times as long as greatest width. Abdomen velvety brownish black, with dark hair; tergites broad; sternites small and weakly sclerotized. Basistyle subquadrate; dististyle about as long as basistyle, the end with a depressed shiny area, the inner angle of which bears a small tooth; ventral plate broad, rounded distally, the arms short, slightly expanded distally, and without lateral projections.

Pupa. Length 2-3 mm. Respiratory organ about two-thirds length of pupa, of six filaments arising from a short petiole; dorsal pair of filaments diverging strongly upward from the other two pairs, the petiole about three times as long as broad; petiole of median pair slightly shorter and directed somewhat laterad; petiole of third pair directed somewhat mediad, and with the petiole about as long as in first pair. Trichomes three or four on each side, slender, rather long. Terminal hooks small, blunt. Cocoon wall-vase-shaped, well formed but rather loosely woven, with a tapering anterior median projection.

Larva. Mature specimens 6.5 mm long. Head capsule with dark head spots; fulvous area very light or absent; isthmus wide between

anterior and posterior median groups; epicranial plate fumeous with ventrolateral spots present, one on each side of the epicranial plate at about level of the apex of throat cleft. Throat cleft U-shaped, slightly narrowed posteriorly and rounded apically; about as wide as long; extending about one-third distance from posterior margin of head capsule to teeth of submentum. Suboesophageal ganglion never distinctly black. Submentum typical for genus; lateral margins serrate distally with distalmost serrations large and pigmented. Usually two to three long and one to two short epicranial setae present on each side. Distance from apex of outermost tooth of submentum to anterior-most epicranial seta on same side subequal to distance between outermost teeth. Mandible with small teeth having relative lengths 12-7-10 from distalmost basad; inner subapical margin with a large anterior serration which is more or less flat on the anterior margin and forms an angle of about 90° with the margin, followed by two to four small, anteriorly pointing serrations. Antenna almost as long as distance from base to posterior margin of head capsule; segment length ratios, base to apex, 7-6-5-1; uniformly yellow except for slightly darkened third segment. Each cephalic fan with about 53 rays. Length of maxillary palpus three times basal width. Pupal respiratory histoblast with six filaments. Abdomen of preserved specimens mottled brown with light intersegmental areas. Anal gill consisting of three compound lobes. Anal cross-piece well sclerotized, areas between arms lightly sclerotized; ventral arms slightly longer than dorsal arms. Anal hooks about 10 to a row in 50 to 60 rows.

Distribution. Hudsonian to Transition zones in Alaska, New York and Pennsylvania.

New York State Records

Hamilton co.—Inlet vicinity, June 10th-July 1st (pupa); May 28th-July 2d (larva)

Biology. Larvae of *S. gouldingi* have been found only in a few permanent streams flowing through heavily wooded areas in the Adirondacks, in May, June and July. In June 1952 about 8 per cent of the black fly larvae collected were of this species. The senior author found the species in Pennsylvania, in a small stream flowing from a blueberry-sphagnum bog, and again in a small stream, about six feet wide and three inches deep, flowing over rocks through sphagnum and royal fern, the pupae being found on the under sides of the rocks. There is probably only one generation a year. DeFoliart (1951) concurs in this opinion.

Little is known of the egg-laying or adult-feeding habits of this species. Adults were not taken in collections of annoying black flies.

Simulium (Eusimulium) latipes (Meigen)

(Figs. 46, 68, 74, 97, 112)

Atractocera latipes Meigen, 1804:96

Simulia latipes (Meigen) : Meigen, 1818:297

Melusina latipes (Meigen) : Lundstroem, 1911:11, 16-17, figs. 2, 13

Simulium latipes (Meigen) : Edwards, 1915:38-39, figs. 1m, 4f, 5a; Edwards, 1920:239-41, figs. 1j, 2e, 3d, 4i (female, pupa, larva); Friederichs, 1921:52, 59, 66, figs. 15h, 16c, 20c, d, 21b; Puri, 1925:352-54, fig. 16 A-H (pupa, larva); Freeman, 1950:147-50, figs. 6-8 (male); Nicholson and Mickel, 1950:40-41, figs. 26 A-E (male, female, pupa); Grenier, 1953:105-6, figs. 19, 21, 35, 60, 97, 98, 104, 172, 181, 192 (female, male, pupa, larva)

Cnetha latipes (Meigen) : Enderlein, 1921a:199

Simulium (Eusimulium) latipes (Meigen) : Twinn, 1936:121 (pupa); Sommerman, 1953:271, 272, fig. 31 (larva)

Female. General color dark grayish brown. Wing length 2.5-3 mm. Frons pale gray with concolorous hair, at narrowest slightly less than half width of clypeus, widened above; clypeus gray with gray hair. Antenna uniformly dark brown to black; palpus dark. Mandible serrate, maxilla with retrorse teeth. Scutum dark brown with fine recumbent yellow hair, paler and grayer along the anterior margin and sides where there is also a dusting of grayish white. Scutellum yellowish brown, with dense, erect and recumbent yellow hair. Post-scutellum dark, without recumbent scales. Pleuron grayish to brown; pleural tuft whitish. Wing with hairs at base of costa mostly pale, those on stem vein dark; subcosta with scattered hairs beneath. Halter pale yellow; the stem darkened. Legs mostly dark brown; each tibia with whitish pollen and hairs on anterior surface, most extensive on fore tibia, less so on others; hind basitarsus five to seven times as long as broad, nearly parallel-sided; calcipala short and broad; pedisulcus deep; basal projection of claw slightly more than half as long as claw, ovate. Abdomen dark brownish; basal fringe pale yellow; tergite 2 broad, rounded behind; tergites 3 to 7 narrow, the seventh widest; tergite 8 very broad; sternite 8 broad. Anal lobe subquadrate, often with a distinct notch ventroposteriorly; cercus about as broad as long, longer dorsally than ventrally; ovipositor short, rounded; stem of genital fork rather stout, not expanded at base; arms expanded, dorsally sclerotized and weakly serrate.

Male. Darker than female, with pale hairs entirely golden yellow. Wing length 2.3-2.7 mm. Scutum dark brown, with hairs golden yellow; humeri and scutellum paler, the latter with erect brown, and recumbent golden hairs. Pleuron reddish black with thin gray

pruinosity; pleural tuft blackish brown. Hairs of wing all dark. Halter mostly brown, the distal margin paler. Legs blackish brown, the femora with some yellowish hair, the fore tibia distinctly whitish pollinose and pilose anteriorly; hairs elsewhere mostly dark; hind tibia slightly swollen, widest at distal fourth, about five times as long as greatest width; hind basitarsus four times as long as wide. Abdomen velvety dark reddish brown, with dark hair; basal fringe long; tergites broad; sternites rather narrow, sclerotized. Basistyle subquadrate; dististyle about two-thirds length basistyle, the end obliquely truncate, triangular, the inner angle with a small tooth; ventral plate broad, rounded distally, the arms short, tapering, without lateral projections; median sclerite Y-shaped; dorsal sclerite broad.

Pupa. Length 2.5-3 mm. Respiratory organ about as long as pupa, of four slender filaments from a short petiole; dorsal pair of filaments on a very short petiole; petiole of ventral pair of filaments slightly longer. Dorsum of thorax smooth, the trichomes very slender, rather long. Terminal hooks very short, blunt. Cocoon wall-vase-shaped, rather broad anteriorly, with a long, usually tapering median projection from the anterior margin.

Larva. Mature specimens 6.5 mm long. Head capsule with dark brown head spots; no fulvous area on frontoclypeal plate around head spots; anterior and posterior median groups separated by moderately broad isthmus; epicranial plate fumeous brown with ventrolateral spots present. Throat cleft U-shaped, slightly narrowed posteriorly and rounded apically (somewhat flattened on some specimens); about as wide as long and extending about one-third distance from posterior margin of head capsule to teeth of submentum. Suboesophageal ganglion never distinctly black. Submentum typical for genus; lateral margins serrate distally with distalmost serrations large and pigmented. Usually one to three long and one to two short epicranial setae present on each side. Distance from apex of outermost tooth of submentum to anteriormost epicranial seta on same side slightly more than distance between outermost teeth. Mandible with small teeth having relative lengths of 10-6-8; inner subapical margin with a large anterior serration which is more or less flat on the anterior margin, followed by two to four small anteriorly pointing serrations. Antenna almost as long as distance from base to posterior margin of head capsule; segment length ratios, base to apex 8-10.3-4.8-1; uniformly yellow except for lightened ventral portion of segment 1. Each cephalic fan with about 45 rays. Length of maxillary palpus slightly more than three times width at base. Pupal respiratory histoblast with four filaments. Abdomen of preserved specimens mottled

light brown with light intersegmental areas. Anal gill made up of three compound lobes. Anal cross-piece well sclerotized, areas between arms lightly sclerotized; ventral arms slightly longer than dorsal arms. Anal hooks about 10 to a row in about 80 rows.

Distribution. Holarctic. In the Nearctic region, Hudsonian and Canadian zones from Alaska and Maine to California and Connecticut.

New York State Records

Franklin co.—Tupper Lake, May 29th (pupae)

Herkimer co.—inlets to South Inlet, Old Forge area, June 8th (adult); May 29th-June 10th (pupa); May 9th-June 24th (larva)

Biology. *S. latipes* is not a common species in the Adirondacks. Larvae were found only in temporary streams which continue to flow until at least mid-May or June. Edwards (1920) reported that this species overwinters in the larval stage. In the Adirondacks larvae were not found until May 1952, although frequent collections were made in these streams earlier in the season. In the Adirondacks this species probably overwinters in the egg stage. Larvae are first found in May and the major portion of pupation takes place in June. Since *S. latipes* larvae closely resemble those of *S. pugetense*, and to a lesser degree *S. gouldingi* and *S. aureum*, caution should be taken in determining this species. Edwards (1920) stated that there is probably one generation a year. This agrees with observations made in the Adirondacks.

Although Edwards reported in 1915 that *S. latipes* was not a pest species, in 1920 he reported instances of its being annoying to man. Smart (1944) reported this species to be a pest. Hocking and Richards (1952) reported that this species is not a pest in Labrador. *S. latipes* is not a pest in the Adirondacks, but then, it is not present in large numbers. A few females of the subgenus *Eusimulium* which may be *S. latipes* were collected along with other species of annoying adults.

Simulium (*Eusimulium*) *pugetense* (Dyar and Shannon)

(Figs. 31, 107)

Eusimulium pugetense Dyar and Shannon, 1927:23, figs. 121-23; Stains and Knowlton, 1943:271, figs. 28, 36 (female, male)

Simulium (*Eusimulium*) *pugetense* (Dyar and Shannon): Stone, 1952:92; Sommerman, 1953:271, 273, fig. 33 (larva)

Simulium (*Eusimulium*) *quebecense* Twinn, 1936:117-18, fig. 6B (female, male, pupa)

Female and Male. No reliable character has been found for distinguishing them from *latipes*.

Pupa. Agreeing with the description of *latipes* except that the respiratory filaments are somewhat less widely divergent, the dorsal pair is slightly thicker than the ventral pair, and the cocoon is simple with a thickened anterior rim but with no anterior median projection.

Larva. Mature specimens 7 mm long. Head capsule with dark brown head spot; fumeous area absent on frontoclypeus; isthmus wide between anterior and posterior median groups; epicranial plate fumeous with ventrolateral spots present, one on each side of the epicranial plate at about the level of the apex of the throat cleft. Throat cleft U-shaped, slightly narrowed posteriorly and rounded to slightly pointed apically; about as wide as long; extending about one-third distance from posterior margin of head capsule to teeth of submentum. Suboesophageal ganglion never distinctly black. Submentum typical for genus except: lateral margins serrate distally with distalmost serrations large and pigmented. Usually four long and one to two short epicranial setae present on each side. Distance from apex of outermost tooth of submentum to anteriormost epicranial seta on same side slightly less than the distance between outermost teeth. Mandibles with small teeth having relative lengths 12-9-11 from distalmost basad; inner subapical margin with large anterior serration which is more or less flat on anterior margin and forms angle of about 90 degrees with margin, followed by two to four small anteriorly pointing serrations. Antenna almost as long as distance from base to posterior margin of head capsule; segment length ratios base to apex 9.4-12.4-5.8-1; uniformly yellow except for lightened ventral portion of segment 1. Each cephalic fan with about 37 rays. Length of maxillary palpus slightly more than three times width at base. Pupal respiratory histoblast with four filaments. Abdomen of preserved specimens mottled brown with light intersegmented areas. Anal gill of three compound lobes. Anal cross-piece well sclerotized; ventral arms slightly longer than dorsal arms. Anal hooks 11 to 13 to a row in about 77 rows.

Distribution. Canadian zone from Alaska, Ontario and Maine, to California, Utah and West Virginia.

New York State Record

Oneida co.—Crystal brook, Forestport, April 10th, 12th, 15th (pupa, larva)

Biology. *S. pugetense* is very rare in the Adirondacks. It was found only in the Forestport area in Crystal brook. This is a small spring-fed stream with a bottom of fine sand, dead leaves, twigs and some grass.

Larvae and pupae were collected during the first two weeks in April but were not found thereafter.

Jenkins (1948) reported that the larvae are found in cold waterfalls and mountain streams in Alaska. Hocking and Richards (1952), reported that this species is found in small forest streams and in rather larger streams while in flood. They stated that this species apparently overwinters in the larval stage. Well-grown larvae can be found early in May in Labrador, according to these authors. There is probably only one generation a year. Davies (1950) recorded two generations a year for the species under the name of *S. costatum*.

Davies (1950) recorded this as a severe blood sucker. Hocking and Richards (1952) noted that it was rarely annoying.

***Simulium (Neosimulium) vittatum* Zetterstedt**

(Figs. 1, 3, 13, 29, 47, 67, 70, 77, 95, 105, 113)

Simulia vittata Zetterstedt, 1838:803; Bequaert, 1945:115

Simulium vittatum Zetterstedt: Coquillett, 1898:69 (female); Johannsen, 1903:383-86, pl. 35, figs. 1-3 (female, pupa, larva); Forbes, 1912:47-48, figs. 23-25 (female, larva); Emery, 1913:324-48, pls. XXXVIII-XLII (female, male, pupa, larva); Malloch, 1914:53-55, pl. 2, fig. 9, pl. 4, fig. 4, pl. 5, fig. 2 (female, male, pupa, larva); Hungerford, 1914:368-369, 374-381, pls. XLIII-XLV (anatomy); Jobbins-Pomeroy, 1916, pl. II, fig. 5, pl. IV, fig. 2, pl. V, fig. 1, text figs. 11, 13 (male, pupa, larva); Dyar & Shannon, 1927:28-30, figs. 74, 75, 106-8 (male, female); Hearle, 1932:12, fig. B; Knowlton and Rowe, 1934a:582, figs. 3, 4 (female); 1934b:fig. 1 (female); Stains and Knowlton, 1943:274, figs. 73, 74, 92-94 (female, male); Davies, 1949:20 (male, pupa); Nicholson and Mickel, 1950:42-46, fig. 28 A-E (female, male, pupa)

Wilhelmia vittata (Zetterstedt): Enderlein, 1921c:46

Simulium (Simulium) vittatum Zetterstedt: Twinn, 1936:132-34, pl. 1, figs. 1, 3, 6, text fig. 10 (female, male, pupa)

Simulium (Neosimulium) vittatum Zetterstedt: Rubzov, 1940:116, 130; Sommerman, 1953:267, 268, fig. 21 (larva)

Simulium tribulatum Lugger, 1896:179-81, figs. 147-51 (female, male, pupa)

Simulium glaucum Coquillett, 1902:97 (male)

Simulium venustoides Hart, in Forbes, 1912:42-44, figs. 13-15 (female, male) (Lectotype male designated by Frison, 1927)

Simulium decorum Walker: Dyar and Shannon, 1927:30, figs. 133, 134 (male only)

Female. General color ashy gray with brownish markings on thorax and black markings on abdomen. Wing length 3-3.5 mm. Frons opaque gray, with white hair, at narrowest about five-eighths width of clypeus, widened above; clypeus gray, with white hair, about as broad as long. Antenna with scape and pedicel dark reddish, the flagellum black with pale pubescence. Palpus black, the last segment longer than the first three, slender. Scutum gray, clothed with short, recumbent gray hair and with a blackish brown pattern as in figure 13. Scutellum dark gray with erect white hair. Postscutellum velvety

black, with gray reflections. Pleuron gray, with a narrow blackish band across the upper sternopleuron; pleural tuft white. Wing veins yellowish; hairs at base of costa and on stem vein white; subcosta bare. Halter nearly white, with extreme base darkened. Coxae, femora, and tibiae mostly dark gray, with white hair; trochanters reddened; fore tibia flattened, the basal three-fourths white; approximately basal halves of mid and hind tibiae white; fore tarsus cylindrical, black; other tarsi black except for white on basal half of mid-basitarsus and basal two-thirds of hind basitarsus; hind basitarsus about 7.5 times as long as wide, nearly parallel-sided; calcipala very short; pedisulcus deep; claw simple. Abdomen gray with velvety black pattern, extensive basally and dividing into three tapering stripes posteriorly; sides with transverse black spots on segments 3 to 6; basal fringe white. Sternites 1 to 7 not sclerotized. Anal lobe narrow, expanding ventrally and then narrowed to a blunt point; lower half usually less pigmented; cercus subquadrate, rounded behind, nearly twice as wide as long; ovipositor short, with halves broadly rounded, diverging, with strong setae on margin; genital rod with a swollen knob at base; arms divergent and each with a narrow ventral lobe and just beyond a broader, blunt, dorsal lobe.

Male. Wing length 2.25-3 mm. Scutum velvety brownish black, with appressed yellow hair, and in certain lights a pair of grayish stripes from anterior margin, tapering rapidly and reaching middle of scutum; sides and posterior declivity usually gray in reflected light. Scutellum dark, with erect pale hair. Pleuron mostly dark grayish; pleural tuft white to brownish. Wing veins yellow brown; hairs at base of costa and on stem vein dark brown; subcosta bare. Halter white, the stem dark. Legs dark brown, with white markings as follows: a patch on fore tibia anteriorly, extending to two-thirds of outer margin, one-third of inner margin; basal halves or less of mid and hind tibiae, basal two-thirds of hind basitarsus, and base of hind second tarsus. Abdomen mostly velvety black; basal fringe dark; sides of tergites 5 and 6 externally silvery gray, with some pale hair; sternites 3 to 8 sclerotized. Basistyle short, stout, nearly as broad as long; dististyle about two-thirds length of basistyle, flattened, curved inward, with three or four teeth on outer margin distally; ventral plate broader than long, the center somewhat curved ventrally; basal arms short, stout; paramere narrow, the arm with several strong teeth.

Pupa. Length 3-3.5 mm. Respiratory organ about two-thirds length of pupa, usually consisting of 16 filaments in eight pairs arising at varying distances from the base. Dorsum of thorax smooth, the trichomes short, slender. Terminal hooks very short. Cocoon wall-vase-

shaped, rather loosely woven, the anterior margin sloping backward, somewhat thickened.

Larva. Mature specimens 9 mm long. Head capsule with dark brown head spots; narrowly infuscated around median row, anterolateral and posterolateral head spots; with narrow isthmus between anterior and posterior median groups; degree of pigmentation quite variable; epicranial plate fumeous brown. Throat cleft widest at posterior margin, apex varying from a blunt point to nearly flattened; twice as wide as long; extending slightly more than one-fourth distance from posterior margin of head capsule to teeth of submentum. Suboesophageal ganglion distinctly black. Submentum typical for genus; lateral margins serrate. Usually four to five long and one to two short epicranial setae present on each side. Distance from apex of outermost tooth of submentum to anteriormost epicranial seta on same side slightly more than one-half distance between outermost teeth. Mandibles with small teeth having relative lengths 20-14-17 from distalmost basad; inner subapical margin with large double tooth, anterior portion twice as long as posterior. Antenna slightly more than one-half as long as distance from base to posterior margin of head capsule; segment length ratios base to apex 6.2-9.2-8-1; segment 1 brown except for basal ventral light spot, segment 2 brown except for distinctive single lobed light area on ventral portion extending 0.5 to 0.7 distance from base to apex, segments 3 and 4 uniformly brown. Each cephalic fan with about 50 rays. Length of maxillary palpus slightly more than three times width at base. Pupal respiratory histoblast with 16 filaments. Abdomen of preserved specimens mottled black with light intersegmental areas. Anal gill consisting of three compound lobes (small ventral auxiliary lobes not always visible). Anal cross-piece well sclerotized, areas between arms lightly sclerotized; ventral arms subequal or slightly longer than dorsal arms. Anal hooks 18 to 24 to a row in 67 to 88 rows.

Distribution. Hudsonian, Canadian, Transition and Upper Austral zones from Alaska and Greenland to Southern California and Georgia.

New York State Distribution

Common and widespread species, with the adults present from April to November.

Biology. The biology of *S. vittatum* has been fairly completely studied, probably owing to the ease with which large numbers of eggs, larvae or pupae can be collected from readily accessible areas. The

eggs are said to be between 0.27 and 0.3 mm in length (DeFoliart, 1951): 0.25 (Wu, 1931). Malloch (1914) reported that eggs take nine to 15 days to hatch while Wu (1931) reported that they require only four to five days. These eggs are not resistant to desiccation according to Wu (1931). Larvae of this species are found on dam faces, below lake outlets, and below large pools. The species overwinters in the larval stage. DeFoliart (1951) noted that the duration of the larval stage is influenced by the amount of food available. Pupation, however, may occur even during the winter, although this is quite rare. The senior author collected larvae and pupae near Washington, D. C., on February 12th, and an adult emerged from one of the pupae before getting it home. During the summer the pupal period lasts three to four days (DeFoliart, 1951). Adults have been collected flying about on warm days when there was still ice on the lakes and snow on the ground.

S. vittatum lays its eggs in characteristic strings joined by a gelatinous substance. Dead females are often found partially buried in the egg masses. Apparently numerous females lay their eggs in the same spot. The larvae are often so numerous that they appear like a black mossy covering on the dam face. At least three generations a year have been observed in the Adirondacks during the course of a summer. From field observation, it seems probable that there are at least four generations a year, DeFoliart (1951) reported three or more generations a year in the Adirondacks. Davies (1950) stated that there are probably two generations a year in Ontario, while Jenkins (1948) stated that there are two to three generations a year in Central Alaska. The females probably lay about 300 eggs each (300-320 according to Wu, 1931). The pupal period lasts about four days (Wu, 1931).

S. vittatum is rarely annoying to man in the Adirondacks although larvae can be found in large numbers below dams, at lake outlets and below large pools. It has, however, been reported attacking man, horses, domestic animals and "mammals" (Cameron, 1922; Davies, 1950; Dyar and Shannon, 1927; Emery, 1913; Frost, 1949; Hocking and Richards, 1952; Jobbins-Pomeroy, 1916; Knowlton, 1935; Knowlton and Maddock, 1944; Longstaff, 1932; Lugger, 1896; Malloch, 1914; Sailer, 1953; Twinn, 1936).

***Simulium (Simulium) corbis* Twinn**

(Figs. 10, 18, 42, 51, 73)

Simulium sp. O'Kane, 1926:21-22, figs. 2-6 (pupa, larva)

Simulium (Simulium) corbis Twinn, 1936:147-48, fig. 15B (female, male, pupa); Stone, 1952:92, fig. 4 (pupa); Sommerman, 1953:269-70, fig. 24 (larva)

Simulium corbis Twinn, Nicholson and Mickel, 1950:58-60, fig. 32 A-E (male, female)

?*Simulium* (s. str.) *relictum* Rubzov, 1940:425-28, 516-17, figs. 5F, 15E, 92A-K (female, male, pupa, larva)

Female. General color grayish black. Wing length 3-3.5 mm. Frons shining black, divergent above; clypeus dark, covered with a gray pruinosity. Antenna black, scape rarely yellowish. Palpus nearly black. Scutum dark brown, in certain lights lateral thirds and posterior third gray pruinose; a patch at either side of center at anterior margin either black or pale gray depending on light angle; fine hairs of scutum pale yellow; humerus reddish. Scutellum dark brown, with yellowish brown hair curving toward median line. Postscutellum velvety dark brown. Pleuron dark brown with gray pruinosity; pleural tuft yellow. Wing veins pale, with hairs and spinules mostly darker; hairs at extreme base of costa and on stem vein yellow; subcosta with hairs beneath. Halter pale yellow, the stem darker. Fore coxa yellow; femora light to dark brown, usually paler basally; all tibiae white on basal two-thirds; tarsi black except for base of mid basitarsus and most of hind basitarsus; fore basitarsus somewhat flattened; hind basitarsus nearly six times as long as wide, with parallel sides; claw small, curved, with a distinct short tooth near base. Abdomen dark brown, with tergites 6 to 9 subshining; basal fringe pale yellow. Anal lobe quadrate, rounded anteriorly, with very short projections dorsally and ventrally; cercus with anterior margin nearly straight, posterior margin angularly rounded, twice as broad as long; ovipositor short, each half broadly rounded distally; arms of genital rod with a lateral angle near base, a somewhat expanded, sclerotized apex and a sharp sclerotized preapical tooth.

Male. Wing 2.75-3.25 mm. Scutum velvety black except for a pair of oblique spots extending back from humeri, the lateral margins, and the prescutellar declivity, which are gray pruinose in certain lights; hairs of scutum pale yellow. Scutellum dark brown with erect brown and recumbent golden hairs. Postscutellum velvety, nearly black. Pleuron black to reddish; pleural tuft dark brown; hairs at base of costa and on stem vein black; subcosta bare. Halter as in female. Fore coxa yellow; fore tibia with a long silvery white area on anterior surface; dorsal surface of basal half of mid tibia white; hind tibia very narrowly white at base; hind basitarsus with approximately basal half white; rest of legs dark brown to black; flattened area at apex of hind tibia dark brown, hairs surrounding it dark. Abdomen velvety dark brown with brown hairs; grayish pollinose spots on sides of tergites 2, 5 and 6; sternites sclerotized. Basistyle short, two-thirds to five-sixths as long as wide; dististyle about three times as long

as the greatest width, the base swollen but without a basal lobe, somewhat constricted centrally, and with the apex rounded and with only a very small tooth, if any; ventral plate with the central portion strongly compressed so that the two serrate margins are almost in contact; ventroapical angle distinctly produced beyond serrate portion; basal arms divergent, with no lateral projections; parameral hooks gradually lengthening toward center.

Pupa. Length 4-5 mm. Respiratory organ about one-fourth length of pupa, of ten slender filaments on two short stalks, upper one with six filaments, lower with four; upper group consists of two pairs, each with a third filament from the stem; the lower group is of two pairs. Dorsum of thorax smooth, trichomes small. No terminal hooks. Cocoon with a broad anteroventral connection, so that it is boot-shaped; anterior margin with three or four slender loops on each side, making an open basket, the respiratory organ extending little beyond this; main part of cocoon tightly woven.

Larva. Mature specimens 7 mm long. Head capsule with distinct brown head spots; anterior median group separated from posterior median group by wide isthmus; posterolateral head spots less distinct; anterior and median portion of frontoclypeus light yellow, posterior portion with dark fulvous area around head spots. Throat cleft bowed V-shaped, with blunt apical point, widest about one-fourth distance from posterior margin to apex; extending two-thirds distance from posterior margin of head capsule to tip of submentum, with narrow apical extension. Suboesophageal ganglion light, epidermis in throat cleft black. Submentum typical for genus; lateral margin serrate distally. Usually with three long and two short epicranial setae present on each side. Distance from apex of outermost tooth of submentum to anteriormost epicranial seta on same side slightly less than the distance between teeth. Mandible with small teeth having relative lengths of 16-12-13 from distalmost basad. Antenna long, about three-fourths as long as distance from base to posterior margin of head capsule; segment length ratios, base to apex 11-12-6-1; segment 1 with light basal area; segments 1 and 2 light below, yellow above; segments 3 and 4 yellow. Each cephalic fan with about 50 rays. Length of maxillary palpus 3.6 times width at base. Pupal respiratory histoblast with 10 filaments. Abdomen of preserved specimens black with broad white intersegmental areas; segments 7 and 8 lightened ventrally. Anal cross-piece well sclerotized, with areas between arms moderately sclerotized; ventral arms longer than dorsal arms. Anal hooks about 14 to a row in about 94 rows.

Distribution. Hudsonian and Canadian zones from Alaska and Quebec to Minnesota and Maine.

New York State Records

Clinton co.—West Chazy, June 17, 1952 (pupae)

Hamilton co.—Long Lake, May 31, 1950 (pupal pelts and cocoons)

St Lawrence co.—South Colton, June 16, 1952 (pupae)

The synonymizing of *relictum* Rubzov under *corbis* Twinn by Stone (1952) was perhaps rather rash since the claw of *relictum* is figured and described as being without a tooth. This might have been overlooked by Rubzov since it is rather small. Until specimens of *relictum* from Siberia can be studied it would seem best to question the synonymy.

Biology. Twinn (1936) found pupae of *S. corbis* May 22d on the submerged stems of dogwood growing close to the bank of a river in the rapids a short distance below a waterfall. The river was flowing swiftly over a stony bottom; the temperature of the water was 53° F. Pupae of *venustum* and *pugetense* occurred on stones nearby. Nicholson and Mickel (1950) found the immature stages in Minnesota in cold streams associated with *latipes*. Sailer (1953) reported *S. arcticum* and/or *S. corbis* biting man in Alaska. This species is apparently quite rare in New York.

Simulium (Simulium) decorum Walker

(Figs. 23, 24, 43, 61, 114)

Simulium decorum Walker, 1848:112; Dyar and Shannon, 1927:30-31, figs. 69, 70 (female only); Stains and Knowlton, 1943:275, figs. 76, 77 (female); Nicholson and Mickel, 1950:55-58, fig. 31 (female, male, pupa); Grenier, 1953:122-24, figs. 25, 27-29, 31, 40, 65, 71, 117, 169, 188, 205, 206 (female, male, pupa, larva)

Simulium (Neosimulium) decorum Walker: Rubzov, 1940:130

Simulium (Simulium) decorum Walker: Sommerman, 1953:269, 272, fig. 28 (larva)

Simulium piscicidium Riley, 1870:367, fig. 143 (female, male, pupa, larva); Osborn, 1896:56, fig. 20; Malloch, 1914:45-46, pl. 6, fig. 5 (female, male, pupa); Johannsen, 1934:63

Simulium venustum var. *piscicidium* Riley: Johannsen, 1903; 381-83, pl. 37, figs. 2, 5, 7, pl. 38, figs. 1-3 (female, male, larva, pupa)

Simulium venustoides Hart, in Forbes, 1912:43-44, fig. 13 (female only, not the male lectotype)

Simulium nölteri Friederichs, 1920:567; 1921:46-47, fig. 19a, (male, larva); Puri, 1925:303-33, text figs. 1-6, pls. VIII-IX (pupa, larva)

Simulium subornatum Edwards, 1920:227-28, figs. 1c, 2b, 3b, 4d, 5b (female, male, pupa, larva); Rubzov, 1940:428-29, figs. 1E, 5G, 60, 8A, B, 16Z, 21I, 58K, 62D, 65B, C, Q, S, 72E (female, male, pupa, larva)

Simulium tenuimanus Enderlein, 1921b:222

Simulium decorum katmai Dyar and Shannon, 1927:31, figs. 56-57 (female); Hearle, 1932:13

Simulium (*Simulium*) *ottawaense* Twinn, 1936:146-47, fig. 15A (female, male, pupa); Davies, 1949:20 (male, pupa)

Simulium nölteri Friederichs: Smart, 1944:figs. 11o, 13d, 15b, 17c (male, pupa, larva)

Female. General color grayish black, subopaque. Wing length 3-3.5 mm. Frons black, thinly dusted with gray, divergent above; clypeus more distinctly gray, with fine whitish hairs. Antenna dark brown, the scape, pedicel and base of first flagellar segment orange brown. Palpus nearly black. Scutum distinctly convex in lateral view, blackish brown, thinly covered with gray pollen, particularly laterally and posteriorly, sparsely covered with fine white or yellowish, recumbent hairs. Humerus usually somewhat reddened. Scutellum nearly black, with erect black hairs and recumbent fine pale hairs. Post-scutellum velvety gray. Pleuron velvety grayish black, the pleural membrane more reddish; pleural tuft pale. Wing veins pale brown, the hairs and spinules mostly darker; hairs at base of costa and on stem vein pale yellow; subcosta with fine hairs beneath. Halter pale yellow, with stem slightly darker. Fore coxa yellow, with whitish pruinosity; fore femur slightly darker; fore tibia yellow brown, with apex darkened, dorsal surface mostly white; fore tarsus black, the first segment somewhat flattened; mid and hind coxae somewhat darkened; rest of mid and hind legs yellowish except for the considerable whitening of tibiae and black at apices of basitarsi, with rest of tarsi black except base of second hind tarsus; claw simple. First and second abdominal segments dark brown, with basal fringe yellowish; third segment silvery whitish; tergites 4 to 5 opaque brownish black; tergites 6 to 9 subshining black with a thin dusting of gray; sternites 1 to 7 not sclerotized; anal lobe in lateral aspect narrow above, broadened and rounded below with a short posteroventral projection; cercus subquadrate, with rounded posterior margin; ovipositor short, each half with inner margin sclerotized, slightly concave; arms of genital rod tapering, each with a rather broad, blunt, dorsal, subapical tooth.

Male. General color dark brown, legs paler. Clypeus with gray pruinosity. Scutum strongly convex dorsally in lateral view, dark brown, with abundant fine yellow hairs; anterior, to either side of central portion, posterior declivity and narrow marginal portion on sides gray by reflected light. Scutellum brown, with erect dark hairs, and a few fine, recumbent, yellow hairs. Pleuron mostly reddish brown with a thin grayish pruinosity. Wing veins yellowish brown; subcosta without hairs. Halter yellow, the base darkened. Legs mostly yellowish brown, with tarsi darker; tips of femora darkened; fore tibia with large white patch anteriorly, and bases of other tibiae whitened; fore basitarsus flattened. Abdomen dark brown; basal fringe brown; whitish pru-

inosity on sides of tergites 2, 5 and 6; sternites 3 to 7 sclerotized. Basistyle subquadrate; dististyle about three times as long as broad, twice as long as basistyle, somewhat flattened, apically rounded, with a distinct subapical tooth; ventral plate narrow medially with a hairy angular ventral keel; basal arms diverging, without lateral projections; paramere subtriangular, the arm with a number of hooks.

Pupa. Length 3.5-4.5 mm. Respiratory organ about 0.4 length of pupa, with eight filaments consisting of a dorsal pair with a short petiole, a second transverse pair without petiole arising just below dorsal pair, this with inner filament slightly larger than the outer one, and two more ventral pairs on short petioles, that of the ventral pair longer. Dorsum of thorax smooth; trichomes short, simple; abdomen with very short, acute terminal hooks. Cocoon wall-vase-shaped, consisting of woven strands, slender and more tightly woven posteriorly, thicker and more loosely woven anteriorly.

Larva. Mature specimens 8 mm long. Head capsule with light head spots; dark fulvous area around median row forming H-shaped dark area on posterior two-thirds of frontoclypeus with horizontal line formed by moderately wide isthmus between anterior and posterior median groups; medium posterior fulvous area also present; fulvous area not extending laterad beyond inner edge of anterolateral group; anterolateral and posterolateral head spots obscurely pale; epicranial plate fumeous brown with light yellow area just anterior to apex of throat cleft, widening gradually anteriorly, extending to anteroventral margin of head capsule. Throat cleft bulbous; slightly longer than basal width; pointed apically; widest about one-third distance from posterior margin to apex; extending about one-half of distance from posterior margin of head capsule to teeth of submentum. Suboesophageal ganglion light, never distinctly black. Submentum typical for genus. Usually three or four long and one or two short epicranial setae present on each side; lateral margin serrate distally. Distance from apex of outermost tooth of submentum to anteriormost epicranial seta on same side slightly less than distance between outermost teeth. Mandible with small teeth having relative lengths 20-13-14 from distal-most basad. Antenna slightly more than one-half as long as distance from base to posterior margin of head capsule; segment length ratios, base to apex, 8-11.2-9.4-1; uniformly yellow except for light basal area on first segment beneath. Each cephalic fan with about 50 rays. Length of maxillary palpus about two and one-half times width at base. Pupal respiratory histoblast with eight filaments. Abdomen of preserved specimens dirty gray to brown with light intersegmental areas. Anal cross-piece well sclerotized, areas between arms not sclero-

tized; ventral arms longer than dorsal arms. Anal hooks 9 to 16 to a row in about 74 rows.

Distribution. Holarctic. In the Nearctic region, Hudsonian, Canadian, Transition and Upper Austral zones from Alaska and Maine to Iowa and Georgia.

New York State Distribution

Common and widely distributed, the adults present from the middle of May to October.

Biology. The eggs of *S. decorum* are laid in large masses, more than one female often being found imbedded in a single mass. According to DeFoliart (1951), the eggs require from less than four to seven days to hatch at 70° F.

Larvae of this species are found almost invariably on dams, at lake outlets, or below large pools. Larvae were found in the Adirondacks in large numbers during the latter part of the summer, especially after the first two weeks in June. Sometimes they entirely cover parts of the face of a concrete dam or the twigs of a beaver dam. DeFoliart (1951) reported that the larval stage lasts 12-16 days during warm weather. Puri (1925) stated that pupae of *S. decorum* (as *S. noelleri*) required five days at 16° C. or 13-15 days at 3.8° C. for maturation. DeFoliart (1951) reported that the pupal stage lasted three to four days at summer temperatures.

Davies (1950) reported that there appear to be two generations of *S. decorum* a year in Ontario.

This species is apparently of little importance as a pest of man, although there are a few records of it annoying man and cows (DeFoliart, 1951; Dyar and Shannon, 1927; Hocking and Richards, 1952; Lugger, 1896; Nicholson and Mickel, 1950).

Simulium (*Simulium*) *fibrinflatum* Twinn

(Figs. 32, 48)

Simulium (*Simulium*) *fibrinflatum* Twinn, 1936:141-42, fig. 13a (female, male, pupa)

Female. General color glossy blackish brown. Wing length 2-2.5 mm. Frons shiny dark brown, about equal in width to clypeus, divergent above; clypeus subshiny, with thin gray pollen. Antenna with scape and pedicel yellow, flagellum dark brown with pale pubescence. Palpus nearly black. Scutum shiny brownish black, with short decumbent yellowish brown hair and, particularly anteriorly and laterally, thin gray pollinosity; humerus yellowish brown. Scutellum dark red-

dish brown, with erect dark hair. Postscutellum velvety brown. Pleuron blackish brown with grayish pollinosity; pleural tuft dark brown. Wing veins yellowish, hairs, including those of stem vein, dark brown; subcosta bare. Halter pale yellow, with extreme base slightly darker. Legs mostly yellowish brown; most of fore tibia anteriorly, basal half of mid and hind tibiae externally, and most of hind basitarsus glistening white; fore tarsus, most of hind tibia, and distal segments of hind tarsus dark brown; fore basitarsus slightly flattened; claw simple. First abdominal segment dark brown, the basal fringe yellowish; second segment mostly silvery gray; tergites 4 and 5 velvety blackish brown; tergites 6 to 9 shining black or brownish; sternites 1 to 7 not sclerotized. Anal lobe triangular, the ventral angle rounded, with the anterior angle slightly notched; cercus rounded quadrate, slightly wider than long; ovipositor with halves short, wider than long, the blunt tips remote; arms of genital rod rather narrowed distally, with a slender, dark, dorsal tooth. .

Male. Wing length 2-2.25 mm. Scutum velvety black with fine brown hair except for a brilliant white patch on each side, with iridescent reflections, one arm of which runs obliquely inward from behind the humerus and the other along the side of the scutum to join with the bluish gray, shiny, prescutellar area. These shiny areas confine the velvety black area to a median stripe widening anteriorly and extending back about three-fifths the length of the scutum, where it is rather broadly joined to a pair of sublateral spots. Scutellum reddish brown with erect dark hairs, no decumbent hairs. Postscutellum velvety brown. Pleuron yellowish to dark brown with some shiny gray areas; pleural tuft dark. Hairs at base of costa and on stem vein black; subcosta bare. Halter pale yellow, with stem dark. Legs dark brown except for yellow fore coxa, some yellowing at bases of all femora, a long white spot on fore tibia, a white spot at base of each mid and hind tibia on outer side approximately one-third length of tibia, and yellow on most of hind basitarsus. Abdomen velvety black with dark brown hair; iridescent spots on sides of tergites 2, 6 and 7; sternites 3 to 7 sclerotized. Basistyle short, about three-fifths as broad as long; dististyle about three times as long as greatest width, flattened, slightly constricted medially, apex rounded, with a small spine, the base with no strong protuberance or spine; ventral plate with central portion a narrow trough, slightly narrowed at base, truncate apically, a few teeth on margin laterally; basal arms, divergent, each with a strong lateral projection; paramere subtriangular, the arm with mixed large and small hooks.

Pupa. Length 2.5-3 mm. Respiratory organ less than one-third length of pupa, with six swollen, blunt filaments all arising close to the base. Dorsum of thorax smooth, the trichomes very small. No terminal hooks. Cocoon short and stout, narrowly joined anteroventrally to produce a short collar; anterior margin obliquely rounded, the side with a large oval aperture; respiratory organ scarcely projecting beyond anterior margin of cocoon.

Larva. Mature specimens 5 mm long. Head capsule with distinct brown head spots; anterior median group separated from posterior median group by wide isthmus; posterolateral and mediolateral head spots distinct, posterior portion of frontoclypeus with light fulvous area. Throat cleft broadly bowed U-shaped, as long as width at base; pointed apically, extending slightly less than one-half distance to teeth of submentum. Suboesophageal ganglion not distinctly black, but tinged with faint black. Submentum typical for genus. Usually three long and one short epicranial setae present on each side. Distance from apex of outermost tooth of submentum to anteriormost epicranial seta on same side slightly less than distance between outermost teeth. Mandible with small teeth having relative lengths of 11-10-9 from distalmost basad. Antenna long, length subequal to distance from base to posterior margin of head capsule; segment length ratios, base to apex 10-11-5-1; segments 1 and 2 yellow above, light below; segments 3 and 4 yellow. Each cephalic fan with about 43 rays. Length of maxillary palpus about 3.5 times width at base. Pupal respiratory histoblast with six stout filaments. Abdomen of preserved specimens blackish brown with light intersegmental areas. Anal cross-piece well sclerotized, with areas between arms moderately sclerotized; ventral arms longer than dorsal arms. Anal hooks 13 to 18 to a row in about 81 rows.

Distribution. Alleghanian from Ontario and Maine to Virginia.

New York State Records

Clinton co.—Altona, June 17th; Peru, June 22d (pupae).

Biology. Since this species has been collected infrequently, not much can be said of its biology. The larvae and pupae have been found in rushing water of rivers, and also in small permanent streams. They have been found on moss at several localities, but may also occur on other vegetation and on twigs. There are probably several generations a year, at least in the South, since the senior author collected pupae both in late May and in the second week of September in Virginia.

Simulium (Simulium) jenningsi Malloch

(Figs. 11, 12, 21, 40, 53, 69)

Simulium venustum var. a, Johannsen, 1903:381, pl. 37, figs. 8-14; pl. 38, figs. 4-6 (female, male, pupa, larva); 1934:64 (pupa, larva)

Simulium jenningsi Malloch, 1914:41-43, pl. III, fig. 1, pl. V., fig. 12 (female, male, pupa, larva)

Simulium jenningsi jenningsi Malloch: Nicholson and Mickel, 1950:52-54, fig. 29 A-F. (female, male, pupa)

Simulium (Simulium) nigroparvum Twinn, 1936:142-44, fig. 13b (female, male, pupa); Cox, 1938:443-47, pl. 1-3 (female anatomy); Underhill, 1944:3-12, figs. 2-5 (female, male, pupa, larva)

Female. General color glossy black. Wing length 2-2.3 mm. Frons shiny black, divergent above, at narrowest narrower than clypeus, which is slightly longer than wide, grayish pollinose, subshining, with sparse dark brown hairs. Antenna with scape and pedicel reddish brown, flagellum blackish brown with pale pubescence. Palpus dark brown. Scutum shiny brownish black, clothed with short, yellowish brown, decumbent hairs, with anterior portion laterally back to wing base with thin grayish pollinosity with pink and greenish reflections. Scutellum velvety brownish black with a border of long erect black hairs, but no fine recumbent hairs. Postscutellum velvety dark brown with yellowish reflections anteriorly. Pleuron shiny black with grayish pollinosity; pleural tuft brown. Wing veins pale brown, the hairs and spinules slightly darker; hairs at base of costa light brown; those of stem vein dark brown to black; subcosta bare; radius bare to shortly beyond base of radial sector, followed by a single row of rather stout, short hairs dorsally; radial sector with slender hairs beneath. Halter pale yellow, the stem dark brown. Fore coxa and femur light yellow with concolorous hair, or femur somewhat darkened; fore tibia flattened, dark, the anterior surface with a large patch of silvery white pollen; fore tarsus black, with dark hair, basitarsus flattened; mid and hind coxae dark; mid leg mostly yellowish to brownish yellow, tip of tarsus darker; some whitish pollen on external surface of tibia basally; hind femur and tibia somewhat darkened, the basal half of hind tibia with white pollen externally; hind basitarsus about six times as long as wide, parallel-sided, yellow except at apex; claw simple. First and second abdominal segments dark brown, the basal fringe yellowish; third segment mostly silvery whitish; tergites 4 and 5 velvety black, that on 4 tapering laterally, that on 5 smaller; tergites 6 to 8 shining brown; sternites 1 to 7 not sclerotized. Anal lobe subtriangular, with blunt apex pointing anteriorly and small subapical spur; dorsal and ventral margins concave, posterodorsal and posteroventral produced; cercus with posterior margin rounded; anterior margin nearly straight, twice as broad as long, with hairs scattered

over entire surface; each half of ovipositor broadly rounded distally; arms of genital rod sclerotized, roundly expanded distally, each with slender dark dorsal tooth and a broad, weakly sclerotized ventral lobe.

Male. Wing length 1.75-2 mm. Scutum velvety black except for brilliant white stripes with iridescent reflections running back and somewhat in from humeral angles about one-third length of scutum, the shiny posterior third, and a silvery gray spot on the side just before wing base; fine hairs of scutum dark brown. Scutellum dark brown with erect black hairs, no decumbent hairs. Postscutellum velvety brown. Pleuron yellowish to dark brown with some shiny gray areas; pleural tuft brown. Hairs at base of costa and on stem vein black; subcosta bare. Halter as in female. Legs dark brown except for yellow fore coxa, some yellowing at bases of all femora, a long white spot on fore tibia, a small white spot at base of each mid and hind tibia, and yellow on most of hind basitarsus. Abdomen velvety black, with dark brown hair; iridescent spots on sides of tergites 2, 6 and 7; sternites 3 to 7 sclerotized. Basistyle short, about two-thirds as long as broad; dististyle about 2.8 times as long as greatest width, flattened, slightly constricted medially, the apex rounded with a small spine, the base with no strong protuberance or spine; ventral plate with central portion a narrow trough, slightly narrowed at base, truncate apically, a few teeth on margins laterally; basal arms divergent, each with a strong lateral projection; paramere subtriangular, the arm with about eight large hooks and many smaller ones.

Pupa. Length 2.5 mm. Respiratory organ about one-third length of pupa with 10 slender filaments arranged in four groups from dorsal to ventral as 2-2-3-3. Dorsum of thorax smooth, the trichomes rather long and slender. No terminal hooks. Cocoon short and stout, closely woven, usually joined anteroventrally to produce a short collar; anterior margin oblique, each side with a large aperture; respiratory organ projecting little beyond anterior margin of cocoon.

Larva. Mature specimens 5-5.5 mm long. Head capsule with distinct dark head spots; wide isthmus between anterior and posterior median groups. Throat cleft bulbous; slightly longer than width at base; pointed apically; widest about one-half distance from posterior margin to apex; extending slightly less than one-half distance from posterior margin of head capsule to teeth of submentum. Suboesophageal ganglion never distinctly black. Submentum typical for genus; lateral margins serrate distally. Usually three long and one short epicranial setae present, forming an irregular line on each side, appearing to arise from near lateral margins of submentum. Distance from

apex of outer tooth of submentum to anteriormost epicranial seta on same side slightly more than one-half distance between outermost teeth. Mandibles with small teeth having relative lengths 7-6-4 from distalmost basad. Antennal segment length ratios 10.3-12-3.8-1; from base to apex uniformly pale yellow. Each cephalic fan with 38 to 42 rays. Length of maxillary palpus slightly more than three times width at base. Pupal respiratory histoblast with ten filaments. Abdomen light to moderately yellowish brown, often with a slight green and sometimes red tinge. Anal cross-piece well sclerotized, the areas between arms lightly sclerotized; ventral arms longer than dorsal arms. Anal hooks 12 to 14 to a row in 68 to 70 rows.

Distribution. Eastern Austral region from Manitoba and Maine to Texas and Florida.

New York State Distribution

Found throughout the State where suitable streams are encountered.

Biology. The distribution of this species in New York is apparently spotty. Larvae are found chiefly in large creeks and rivers. It is annoying to humans in the Adirondacks, but has not been taken biting. It is a late-summer pest, being found in July and August. Underhill (1944) reported that, in Virginia, no larvae are present in streams during the winter but that they are abundant in the summer, being first found in March. He further reported that there are three generations a year and that the life cycle lasts about six weeks. Nicholson and Mickel (1950) stated that the pupal stage of *S. jenningsi* (as *jenningsi luggeri*) is completed in two to four days at about 25° C. under laboratory conditions.

Underhill (1944) reported that *S. jenningsi* (as *S. nigroparvum*) adults have been collected 20 to 30 miles from the known breeding places and were present in large numbers ten miles from the nearest known breeding areas. Johnson *et al.* (1938) stated that adults have been taken five to six miles from the nearest known breeding place.

This species is recorded attacking turkeys, horses, mules, cattle and "mammals" (Jobbins-Pomeroy, 1916; Johnson *et al.*, 1938; Malloch, 1914; Nicholson and Mickel, 1950; and Underhill, 1940, 1944).

Simulium (*Simulium*) *parnassum* Malloch

(Figs. 8, 28, 37, 52, 94)

Simulium parnassum Malloch, 1914:36-37, pl. 2, fig. 8, pl. 5, fig. 11 (female);

Dyar and Shannon, 1927:41-42, figs. 65, 66 (female only)

Odagmia parnassa (Malloch): Enderlein, 1925:208

Simulium hydationis Dyar and Shannon, 1927:28 (male). (New synonymy)
Simulium (*Neosimulium*) *hydationis* Dyar and Shannon: Rubzov, 1940:130

Female. A shiny black species. Wing length 2.5-3.25 mm. Frons nearly as wide as clypeus, distinctly widened above, entirely shiny black, with very few black hairs; clypeus black, with a thin gray pruinosity and black hairs. Antenna with scape and pedicel reddish brown, flagellum black. Palpus black, with sensory organ of third segment about one-third length of segment. Scutum entirely black, shiny or weakly grayish pruinose, depending upon the angle of incidence of the light, with short, fine black hairs. Scutellum black, with erect black hair. Postscutellum black, with grayish pruinosity. Pleuron black, with grayish pruinosity, the pleural membrane brown; pleural tuft black. Wing veins yellow brown; hairs at base of costa and on stem vein black; subcosta with hairs beneath. Halter pale yellow, with base dark. Legs mostly blackish, with dark hairs; fore coxa yellow, with yellow hair; fore and mid tibiae anteriorly and hind tibia posteriorly more or less covered by gray pruinosity; apex of hind tibia posteriorly with a flattened area covered with golden yellow hair; fore basitarsus flattened; approximately half of mid basitarsus yellow; approximately two-thirds of hind basitarsus yellow, the posterior surface of the latter with dense yellow hair; calcipala rather narrow; claw long, with a short sharp tooth near base. Abdomen velvety brown, the first segment yellowish brown with basal fringe pale yellow; tergites 6 to 8 shiny; anal lobe subtriangular, narrow dorsally, expanding ventrally, with anterior margin concave, posterior margin nearly straight; cercus rounded subquadrate, about three times as broad as long; ovipositor small, blunt; arm of genital rod expanded and truncate at end, with a short, heavily sclerotized tooth before apex.

Male. Antenna entirely black. Scutum velvety black, with a broad spot on either side of anterior third, with sides, and posterior third, shiny gray-white in certain lights, tinged with pinkish. Scutellum and pleuron as in female. Hairs at base of costa and on stem vein black; no hairs on under side of subcosta. Halter orange yellow, with base dark. Legs black, a small white spot at base of each mid and hind tibia, and the hind basitarsus yellow on basal half posteriorly. Abdomen black, with silvery spot on each side of second segment; basal fringe black; sternites 2 to 7 sclerotized. Basistyle subquadrate, short, slightly broader than long; dististyle slender, about three times as long as basistyle, strongly bent outward just before middle, and then slightly curved inward; ventral plate triangular, the basal arms rather short, without lateral projections; paramere large, triangular, the arm with rather small parameral hooks.

Pupa. Length 3-4 mm. Respiratory organ about one-third length of pupa with six slender filaments arranged in three pairs on short petioles. Dorsum of head and thorax anteriorly strongly reticulate-rugose; trichomes short. No terminal hooks. Cocoon simple, wall-vase-shaped, rather broad, often narrowly closed anteroventrally, the dorsal and anterior profiles each slightly concave.

Larva. Mature specimens 6-7 mm long. Head capsule with indistinct brown head spots; no fulvous area around head spots; epicranial plate fumeous. Throat cleft a long V-shaped notch with straight, anteriorly converging margins, extending about one-third distance from posterior margin of head capsule to teeth of submentum. Suboesophageal ganglion light, never distinctly black. Submentum typical for genus; lateral margins serrate distally. Usually three or four long and one or two short epicranial setae present on each side. Distance from apex of outermost tooth of submentum to anteriormost epicranial seta on same side slightly less than distance between outermost teeth. Mandibles with small teeth having relative lengths of 20-12-9 from distalmost basad; inner subapical margin quite variable with large double tooth or two single teeth. Antenna almost as long as distance from base to posterior margin of head capsule; segment length ratios 11.8-14-8.2-1; uniformly yellow except for light areas beneath on segments 1 and 2. Each cephalic fan with about 32 rays. Length of maxillary palpus slightly less than three times basal width. Pupal respiratory histoblast with six filaments. Abdomen of preserved specimens mottled brown with faint white intersegmental lines. Anal gill made up of three compound lobes. Anal cross-piece well sclerotized, area between arms not sclerotized; ventral arms longer than dorsal arms. Anal hooks about 13 to a row in about 77 rows.

Distribution. Alleghanian from Ontario and Maine to Georgia.

New York State Records

Cattaraugus co.—Allegany State Park, July 20th (adult)

Clinton co.—Plattsburg, August 18th; Saranac, July 17th (adult)

Erie co.—South Wales, July 9th (adult)

Essex co.—Keene Valley, August 16th (adult)

Greene co.—Catskill mountains, August 5th (adult); Kaaterskill Falls, June 18th (larva, pupa)

Hamilton co.—Wheeler creek, July 17th; Bear Brook, July 6th-16th (adult); June 28th (pupa); June 5th, July 17th (larva)

Herkimer co.—Old Forge area; June 2d-August 10th (larva);
July 11th-24th (pupa)

Steuben co.—North Cohocton, July 26th (adult)

Tompkins co.—Ithaca, June (adult)

Warren co.—North River, August 6th-16th (adult)

Biology. Larvae of this species are found in only a few cool, permanent streams in heavily forested areas in the Adirondacks. When they are present, they are often quite numerous. There is apparently only one generation a year in the Adirondacks.

The adults of *S. parnassum* are annoying to humans in the Adirondacks, but have not been collected biting there. Dyar and Shannon (1927) and Hocking and Richards (1952) have stated that this species attacks man. Fuller (1940) found it biting a recently shot woodchuck in Massachusetts.

Simulium (Simulium) pictipes Hagen

(Figs. 20, 44, 58, 71, 88, 104)

Simulium pictipes Hagen, 1880:306-7 (female, male, pupa) 1881:150-51; Howard, 1901:121-23, Johannsen, 1903:374-76, pl. 36, figs. 1-8, pl. 38, figs. 8, 17, 20 (male, female, pupa, larva); Headlee, 1906:876-83, figs. 1-4 (larva); Malloch, 1914:55-57, pl. 2, fig. 10, pl. 3, figs. 2, 4, 5, pl. 4, fig. 2 (female, pupa, larva); Jobbins-Pomeroy, 1916, text figs. 10, 14, pl. 2, fig. 1, pl. 4, figs. 1, 8, pl. 5, fig. 5 (male, pupa, larva); Dyar and Shannon, 1927:27-28, figs. 60, 61, 100-2 (male, female); Johannsen, 1934:62-63, figs. 208, 210, 214-216 (pupa, larva); Smart, 1934:62-65, figs. 1-4; Nicholson and Mickel, 1950:46-47, figs. 27 A-F (male, female, pupa)

Wilhelmia pictipes (Hagen): Enderlein, 1925:207

Simulium (Simulium) pictipes Hagen: Twinn, 1936:134-36, fig. 11A (male, female, pupa)

Simulium (Neosimulium) pictipes Hagen: Rubzov, 1940:130

Simulium innoxium Comstock, 1895:452-53, figs. 535, 536 (pupa, larva)

Female. General color grayish black. Wing length 3.5-4 mm. Frons slightly divergent above, at narrowest about three-fourths width of clypeus, grayish pollinose, with black hairs near eyes, paler hairs centrally; clypeus gray pollinose, with pale hairs. Antenna with scape and pedicel reddish brown, flagellum darker, with pale pubescence. Palpus dark brown. Scutum, when viewed from front, rather pale gray with three dark stripes and a dark spot in front of wing base; each lateral stripe expands anteriorly and is curved; a brownish tinge above lateral dark spot and laterad of lateral stripe; in other lights a pair of white spots on anterior margin, and spots before the wing bases white; scutum clothed with short, fine, pale yellow, recumbent hairs. Humerus pale, with a dark area across middle. Scutellum dark brownish, with erect brownish hair and somewhat more recumbent yellow hairs. Postscutellum velvety brown with a central dark spot

usually present. Pleuron blackish, with gray pollinosity; pleural tuft pale yellow. Wing veins yellow brown, with hairs and spinules darker; hairs at base of costa pale yellow; those of stem vein mixed dark brown to black and white; subcosta with a few hairs beneath; radius bare to base of radial sector except for possibly one or two hairs, followed by more fine hairs and spinules; radial sector with many fine hairs beneath. Halter pale yellow, with stem darkened basally. Legs mostly dark brown to grayish black, with fine, pale yellow hair, although teneral specimens are often caught with the femora and tibiae extensively yellow; fore tibia flattened, with grayish pollinosity; fore basitarsus somewhat flattened; hind basitarsus nearly seven times as long as greatest width, parallel-sided, yellow except for dark apical fourth; calcipala rather short; claw simple. Abdomen dark grayish, with pale yellow and brown hairs. Anal lobe rounded quadrate, with narrow dorsal projection posteriorly, broadly conical ventrally, externally shiny yellow to brown, margined with short yellow hairs; cercus twice as wide as long, with posterior margin rounded, anterior margin nearly straight, covered with dark brown hair; halves of ovipositor small, well separated, the apex of each somewhat acute and curved outward; arms of genital rod sclerotized, the apical expanded portion with a single dorsal tooth.

Male. Generally darker than female. Wing length 3-3.3 mm. The scutum may show three narrow dark lines with the anterior enlarged portion of the lateral line bright white in certain lights, as in female, but usually this pattern is obscured by the generally velvety black color; in reflected light there is a broad band of velvety gray on each side and in front of the scutellum, and a rather large triangular spot extending back and inward from each humerus; fine hairs of mesoscutum pale as in female. Hairs of scutellum erect, entirely black. Postscutellum, pleuron and pleural tufts as in female. Hairs at base of costa black. Halter as in female. Legs almost entirely dark brown to black, with fine, pale yellow hair; grayish pollen of flattened fore tibia scarcely evident; hind basitarsus broader than in female, the basal half usually yellowish brown; calcipala rather short. Abdomen velvety black; basal fringe yellow to brown depending upon light; sternites 3 to 8 sclerotized, that on 8 small. Basistyle subquadrate, about three-fourths as long as dististyle, with ventrolateral angle produced beyond point of attachment of dististyle; dististyle rather long and narrow, slightly constricted about midway, flattened distally, the apex rounded, with no spine; ventral plate broad, finely hirsute with a deep median notch, short, pointed, ventral lip, and short, stout basal arms; paramere very broad basally, the arm with about three hooks.

Pupa. Length about 4.5 mm. Respiratory organ of nine rather short, smooth filaments, somewhat swollen basally, and curving laterally and anteriorly from the center; these are arranged as four pairs, each with a very short base, and a single filament. Two pairs extending ventrally, two dorsally, and the single placed externally and extending ventrally. Dorsum of thorax smooth, the trichomes rather small. Terminal hooks short, curved backward. Cocoon a firm, boot-shaped, rather loosely woven basket, with the respiratory organ entirely surrounded by the anterodorsal extension of the cocoon.

Larva. Mature specimens 11 mm long. Head capsule dark brown with indistinct dark head spots; median row gradually increasing in width giving appearance of an elongate triangle, isthmus narrow. Throat cleft with subparallel sides for about one-half distance to apex, distinctly more convergent beyond, ending in an apical point; extending about one-third distance from posterior margin of head capsule to tip of submentum; about as broad as long. Suboesophageal ganglion distinctly black. Submentum typical for genus except median tooth much larger than outer teeth; lateral margins serrate distally. Usually with six to seven long and three to four short epicranial setae present on each side. Distance from apex of outermost tooth of submentum to anteriormost epicranial seta on same side is slightly less than the distance between outermost teeth. Mandible with small teeth having relative lengths 35-34-30 from distalmost basad. Antenna slightly less than half as long as distance from base to posterior margin of head capsule; segment length ratios base to apex 6.6-10.6-5.4-1; segment 1 dark brown, segment 2 dark brown except for distinctive light area beneath, extending from 0.4-0.8 distance from base of segment to apex, segments 3 and 4 dark brown. Each cephalic fan with about 59 rays. Length of maxillary palpus slightly less than four times width at base. Pupal respiratory histoblast with nine filaments. Abdomen of preserved specimens mottled black with some light areas, indistinct light intersegmental lines present; segments 6 and 7 with median ventral bulge. Anal cross-piece well sclerotized, areas between arms not sclerotized; ventral arms longer than dorsal arms. Anal hooks 18 to 27 to a row in 127 to 135 rows.

Distribution. Canadian and Upper Austral from Minnesota and Quebec to Oklahoma and Georgia.

New York State Records

Clinton co.—Ausable river (type locality) (adult); Schuyler Falls, July 1st (pupa, larva)

Erie co.—Colden, August 9th (adult)

Lewis co.—Black River canal between Boonville and Port Leyden, June 27th; Fall brook near Porter, June 15th (pupa, larva)

Schuyler co.—Cayuta lake, May 5th-8th (pupa, larva)

Tompkins co.—Enfield falls, June 29th; Ithaca, May 23d—September 16th; Taughannock falls, April 26th (pupa, larva)

Biology. The larvae and pupae of *S. pictipes* are characteristically found on flat sedimentary rocks where the water is swift and shallow above small falls. It is particularly abundant in the gorges of the Finger Lakes region. Smart (1934) reported on studies of the biology of this species in and around Ithaca. The larvae are unusual in often being found in "colonies" which look like black moss. These "colonies" are often only a few inches in diameter, appearing to be larvae hatched from a single egg mass.

Smart (1934) reported that the egg is ovoid but without the marked triangulate shape usually associated with black fly eggs. The eggs average $0.37 \times 0.22 \times 0.20$ mm. Oviposition was effected through a thin film of water, or the eggs were laid where the surface was wet with spray. The incubation period of the eggs is 2.5 to 5 days at 25° C. Desiccation kills the eggs. The larvae require four to six weeks to mature and pupate, but the period can be prolonged by reducing the food supply. The pupae require 4.5 days to mature at 25° C. The adults copulate immediately after emergence, and the females lay eggs about a week later. There are at least four and probably five generations per year, the species overwintering in the larval stage.

Gambrell (1933) noted that oviposition took place between 9 and 11 a.m. as a general rule. However, one swarm was detected ovipositing at about 9 p.m. It was also noted that a single female laid between 150 and 200 eggs.

S. pictipes has been reported attacking horses, mules and moose (Jobbins-Pomeroy, 1916; Malloch, 1914; Nicholson and Mickel, 1950). It has not been reported attacking humans.

The *Simulium venustum* complex

The three species *Simulium tuberosum* (Lundstr.), *S. venustum* Say, and *S. verecundum*, n. sp. form a very closely related group, scarcely distinguishable in the pupa, female or the male except for the genitalia. *S. tuberosum* has been recognized as a valid species under several different names for some time. The other two have not been separated up to now, although Nicholson and Mickel (1950) refer to two forms of *venustum* based on the male genitalia. The junior author noted,

in the Adirondacks, that there are at least three and possibly four generations of what was formerly considered to be *S. venustum* between late April and October of each year. However, *S. venustum* is annoying only between late May and early July in this area. This annoyance period coincides well with the emergence of what appeared to be the first generation adults. From this it would appear that either only the first generation is anthropophilic, or that there are two separate species involved.

In 1953 it was observed that fresh specimens of the earlier *S. venustum* larvae had a distinctly reddish tinge on the abdomen, but that the later ones were entirely white. Adults were reared from pupae collected early in May and June from streams with nearly pure cultures of the red larvae and compared with adults reared from pupae collected in July and August from streams with nearly pure cultures of white larvae. There appear to be distinct morphological differences in the male genitalia corresponding to the two forms recognized by Nicholson and Mickel. Both forms are widespread in this country. It therefore is probable that there are two distinct species or that the first-generation *S. venustum* differs both in morphology and habits from the subsequent generations. For the present we consider that these two morphologically and biologically distinct forms represent two distinct, though closely related species. We retain *S. venustum* as the name of the early, annoying species, since Say in the original description remarked that "Its bite is pungent," and it is probable that he collected it between May 5th and June 9th. Because of the difficulty of separating anything but males or fresh larvae, biological data based on females, pupae, or preserved larvae are of little value.

Simulium (Simulium) tuberosum (Lundstroem)

(Figs. 19, 49, 93)

Melusina tuberosa Lundstroem, 1911:14-15, fig. 10 (male)

Simulium tuberosum (Lundstroem): Edwards, 1915:33-34, figs. 1e, 2d, 4b (male, female); Edwards, 1920:234, fig. 4j (pupa, larva); Puri, 1925:346-47, fig. 12 (pupa, larva)

Simulium (S.) tuberosum (Lundstroem): Sommerman, 1953:269, 272, fig. 26 (larva); Grenier, 1953:130-34, figs. 69, 78, 116, 197, 198, 202-4 (female, male, larva, pupa)

Simulium perissum Dyar and Shannon, 1927:43-44, figs. 84, 85, 119, 120 (female, male)

Simulium (S.) perissum Twinn, 1936:138-39, fig. 11c (female, male, pupa)

Simulium vandalicum Dyar and Shannon, 1927:44, figs. 111, 112 (male)

Simulium (S.) turmale Twinn, 1938:51, fig. 4 (male)

Simulium (S.) twinni Stains & Knowlton, 1940:77, figs. C, D, F, I (male)

Female. General color black, subshiny. Wing length 2.5-3 mm. Frons shiny, black, divergent above; clypeus black, with thin gray

pruinosity. Antenna with scape and pedicel reddish brown, flagellum blackish brown with pale pubescence. Palpus dark brown. Scutum brownish black, subshiny, clothed with short yellow decumbent hairs; humeri, areas on scutum surrounding each of them, the sides and the prescutellar area, grayish in certain lights. Scutellum brownish black, with a border of long, erect black hairs, and usually a few recumbent yellow hairs. Postscutellum velvety brownish black. Pleuron brownish black, with thin gray pollinosity; pleural tuft yellowish brown to black. Wing veins pale brown, the hairs and spinules slightly darker; hairs at base of costa, and on stem vein usually black; subcosta with fine hairs beneath; radius with hairs dorsally beyond base of radial sector; radial sector with fine hairs beneath. Halter nearly white. Fore coxa pale yellow, mid and hind coxae dark; all femora mostly dark brown, the fore femur with some yellowish brown basally; fore tibia flattened, the outer surface with a large patch of white; mid and hind tibiae dark brown, with white on basal half of outer surface; tarsi dark brown to black, the mid and hind basitarsi whitened on basal half or more; fore basitarsus somewhat flattened; calcipala rather small; claw simple. Abdomen blackish; basal fringe yellow; tergites 2 to 5 velvety black; tergites 6 to 8 broader, shiny black or dark brown, with short brown hairs; sternites 1 to 7 not sclerotized. Anal lobe narrowly subtriangular, narrow above, somewhat widened below, and rounded; cercus with nearly straight anterior margin, rounded posteriorly, two-thirds as broad as anal lobe and about twice as broad as long; ovipositor with each half broadly rounded distally; arms of genital rod tapering distally, and with a broad, blunt dorsal tooth.

Male. Wing length 2.3-2.6 mm. Scutum velvety black, clothed with dark brown, fine, recumbent hairs. An oblique patch behind each humerus, the sides narrowly, and a transverse band in front of scutellum subshiny, silvery gray in certain lights. Scutellum reddish brown to nearly black, with erect or suberect, brownish to black hairs. Postscutellum velvety brown. Pleuron dark brown to black, with gray pruinosity; pleural tuft dark brown. Hairs at base of costa and on stem vein black; subcosta bare. Halter and leg coloration as in female. Abdomen velvety black, with silvery gray spots on sides of segments 2, 6 and 7; sternites sclerotized. Basistyle subquadrate, about two-thirds length of dististyle, which is nearly three times as long as broad, flattened on distal half; at base dorsally a distinct rounded lobe bearing short, stout spines; apex of dististyle rounded with a subapical internal spine. Ventral plate about as broad as long, finely pilose, with apex truncate, very weakly dentate laterally, with a broad ventral lip; arms

subparallel, with no lateral projections; parameral arm with numerous hooks.

Pupa. Length about 3 mm. Respiratory organ about one-third to one-half length of pupa, with six slender filaments in three pairs, on short petioles, those of the upper pair not diverging more than the others. Dorsum of thorax smooth; trichomes simple, of moderate size. No terminal hooks. Cocoon simple, wall-vase-shaped with no lateral windows, the anterior margin thickened, slightly concave in profile.

Larva. Mature specimens 5.5 mm long. Head capsule with obscure dark head spots; triangular shaped fulvous area with base extending full width across posterior of frontoclypeal plate, becoming narrower anteriorly forming a blunt point about one-half distance from posterior margin of head capsule to apex of labrum. Throat cleft bowed-V-shaped, longer than width at base; pointed apically; widest about one-fourth distance from posterior margin to apex; extending about one-half distance from posterior margin of head capsule to teeth of submentum. Suboesophageal ganglion distinctly black. Submentum typical for genus; lateral margin serrate distally. Usually three or four long and one or two short epicranial setae present on each side. Distance from apex of outermost tooth of submentum to anterior-most epicranial seta on same side slightly less than distance between outermost teeth. Mandible with small teeth having relative lengths 14-8-6 from distalmost basad. Inner subapical margin with large double tooth, anterior portion twice as long as posterior. Antenna long, as long as 0.8 the distance from base to posterior margin of head capsule; segment length ratios from base to apex, 12-12.8-9-1 (Puri, 1925 reported five segments); uniformly yellow except that basal area of venter of first segment is light. Each cephalic fan with about 38 fan rays. Length of maxillary palpus slightly less than three times basal width. Pupal respiratory histoblast with six filaments. Abdomen of preserved specimens black, with broad white intersegmental areas; segments 7 and 8 lightened ventrally. Anal cross-piece well sclerotized; areas between arms not sclerotized; ventral arms longer than dorsal arms. Anal hooks 11 to 15 to a row in about 72 rows.

Distribution. Holarctic. In the Nearctic region, Hudsonian from Alaska to Greenland, and south to the Upper Austral of Texas and Florida.

New York State Distribution

Abundant throughout the State.

Biology. Although Smart (1944) and Davies (1950) reported that there are possibly two generations a year of this species, in the Adirondacks there are at least three and probably four generations a year. In this area, larvae begin emerging from the eggs in early May, somewhat after the first *S. venustum* larvae are found. They occur in all types of permanent streams and by late June or early July are the dominant species present. Females of this species closely resemble those of *S. venustum*. Together they make up a complex which is annoying from late May to early July in the Adirondacks. Although adults of *S. tuberosum* emerge during the entire summer, they are not annoying after early July. There is some evidence to indicate that only the first generation is anthropophilic in the Adirondacks.

S. tuberosum has been reported attacking man, horses, domestic animals and mammals (Davies, 1950; DeFoliart, 1951; Edwards, 1915; Edwards *et al*, 1939; Jamnback, 1952; Hocking and Richards, 1952; and Smart, 1944).

Simulium (Simulium) venustum Say

(Figs. 26, 27, 59, 78, 87, 92)

Simulium venustum Say, 1823:28-29 (female); Johannsen, 1903:379-81, pl. 37, figs. 1-6 (female, male, pupa, larva); Malloch, 1914:43-44, pl. 2, fig. 7, pl. 4, fig. 3, pl. 5, fig. 1 (male, female, pupa, larva); Jobbins-Pomeroy, 1916:3-6, 16, text figs. 1, 2, 5, 8, 12, 15, pl. I, figs. 1-5, pl. II, fig. 2, pl. III, figs. 1-6, pl. IV, figs. 4, 9, pl. V, fig. 2 (male, female, pupa, larva, egg); Puri, 1925:347-48, text fig. 13 (pupa, larva); Hearle, 1932:17-18; Johannsen, 1934:63-64, pl. 24, fig. 213 (pupa, larva); Nicholson, 1945:282-96, figs. 7, 8, 11, 12, 14, 15, 16, 19, 20, 22 (mouth-parts); Nicholson and Mickel, 1950:48-52, figs. 30 A-F (male, female, pupa); Grenier, 1953:129-130, figs. 43, 54, 94, 112, 144, 168, 199-201 (female, male, pupa, larva)

Simulium (Simulium) venustum Say: Twinn, 1936:136-38, pl. I, figs. 2, 5; text fig. 11B (male, female, pupa); Sommerman, 1953:269, 272, fig. 27 (larva)

Simulium molestum Harris, 1841:405 (female)

Simulium minutum Lugger, 1896: fig. 143 (female)

Simulium irritatum Lugger, 1896: figs. 145, 146 (male, female)

Boophtora rileyana Enderlein, 1922:75 (female)

Simulium groenlandicum Enderlein, 1935:363 (female)

(The references to *venustum* with the exception of the original one and those by Puri and Grenier, probably include the new species *verecundum*, which follows),

Female. Agreeing with *tuberosum* with the following exceptions: Pleural tuft usually yellowish; hairs at base of costa and on stem vein usually yellow.

Male. Agreeing with *tuberosum*, with the following exceptions: Fine hairs of scutum often paler, sometimes nearly white; pale areas

behind humeri often somewhat larger, and pale area in front of scutellum somewhat broader. Basistyle subquadrate, about two-thirds length of dististyle, which is about 2.8 times as long as broad, flattened, somewhat constricted medially, the apex rounded with a short spine at apex of inner margin; ventral plate with central portion a compressed, tapering trough, the margins before the rounded apex with teeth, and these margins spread outward, at least slightly; basal arms divergent, without lateral projections; arm of paramere with numerous hooks.

Pupa. Very similar to that of *S. tuberosum*. Respiratory filaments often somewhat longer, from one-half to two-thirds as long as pupa; filaments of dorsal pair often somewhat more divergent than in *tuberosum*.

Larva. Mature specimens 6 to 7 mm long. Head capsule with distinct light yellow head spots; with dark fulvous area around median head spots and median posterior fulvous area also present; fulvous area extending to outer margins of anterolateral head spots or beyond; with median anterior and posterior groups separated by narrow isthmus; with anterolateral and posterolateral head spots present and distinct in most specimens. Epicranial plate fumeous brown, lacking light yellow area just anterior to throat cleft. Throat cleft bulbous arrowhead-shaped; width and length subequal; pointed apically; widest about one-third distance from posterior margin to apex. Suboesophageal ganglion light. Submentum typical for genus. Usually three long and one short epicranial setae present on each side. Distance from apex of outermost tooth of submentum to anteriormost epicranial seta on same side subequal to distance between outermost teeth. Mandible with small teeth having relative lengths of 12-9-8 from distalmost basad. Antenna moderately long, about two-thirds as long as distance from base to posterior margin of head capsule; segment length ratios base to apex 11.8-13.4-11.6-1; uniformly light yellow except for light basal area beneath on first segment. Each cephalic fan with about 51 rays. Length of maxillary palpus almost three times width at base. Pupal respiratory histoblast with six filaments. Abdomen of preserved specimens dirty gray to brown with light intersegmental areas. Anal cross-piece well sclerotized, the areas between arms lightly sclerotized; ventral arms longer than dorsal arms. Anal hooks 9 to 15 to a row in 60 to 75 rows.

Distribution. Holarctic. In the Nearctic region, Hudsonian from Alaska to Greenland, and south to the Lower Austral zone of Mississippi and Texas.

New York State Distribution

Abundant throughout State.

Biology. The separation of what was formerly considered to be the single species *S. venustum* into two species reduces the value of earlier biological studies, although most of the biting and annoyance records do probably refer to the true *venustum*. In the Adirondacks it is annoying to man from late May until early July. It does not bite as readily as *P. hirtipes*, but it may be extremely annoying at times.

It apparently overwinters in the egg stage, the larvae first appearing in large number during the latter half of May. The number of larvae declines rapidly during the spring and early summer, most of them pupating by early July. *S. venustum* is found in both large and small permanent streams. There is apparently only one generation each year.

Simulium (Simulium) verecundum, new species

(Figs. 25, 41)

Female. Not distinguishable from *tuberosum* or *venustum*. Some of the specimens have the hairs of the stem vein and pleural tuft pale as is usual in *venustum*, while others have these dark as usual in *tuberosum*. A slightly shinier appearance to the scutum may be present, but it is not sufficient to serve as a character.

Male. Externally not distinguishable from *venustum*. The ventral plate of the genitalia is shaped much like that of *venustum* except that the lateral serrate portion to each side of the dorsal trough is turned inward so that the teeth are not noticeable from a dorsal view, but approach each other over the central depression, and the apex of the ventral plate is likewise considerably narrowed.

Pupa. Not distinguishable from *venustum*.

Larva. Not separable from *venustum* except in living or freshly killed specimens. In these, the body is entirely white, while in *venustum* the body has a distinctly reddish tinge.

Holotype. Male, Monroe co., Pennsylvania, June 4, 1948, with associated pupal skin and cocoon mounted dry and genitalia on slide (Stone). Paratypes: ALASKA: Anchorage, June 12, 1947 (Stone), 1 female, 1 male; Anchorage-Palmer, June 25, 1947 (Jenkins), 1 female, 2 males; Matanuska, October 6, 1945 (Chamberlin), 1 male. MASSACHUSETTS: Berkshire co., July 5, 1948 (Stone), 4 females,

5 males; MINNESOTA: Mississippi river, Itasca Park, May 23, 1939 (Nicholson), 3 males. NEW YORK: Copake, September 1, 1952 (Stone) 5 females, 5 males; Forestport, July 28 and August 27, 1952 (Jamnback), 2 males; PENNSYLVANIA: Same data as holotype, 3 females, 2 males; SOUTH CAROLINA: Richland co., April 7, 1954 (Stone), 1 female, 1 male; Spartansburg, July 3d to November 1st (Pomeroy; Jennings and King) 26 males; VIRGINIA: New Kent co., May 31, 1941 (Stone) 6 females, 9 males; Charles City co., May 31, 1941 (Stone) 3 females, 2 males; WASHINGTON: Twinn Buttes, June 25, 1941 (Knipling and Yates) 1 male.

Holotype, U. S. National Museum No. 62361. Paratypes, U. S. National Museum, New York State Museum and University of Minnesota.

This species is widespread in North America and the partatypes listed above are selected from many more specimens.

The name is derived from the Latin adjective meaning modest, shy or diffident, in reference to its nonannoying habits.

Biology. Very similar to that of *venustum* except that it appears not to annoy man, it is somewhat later in appearance than *venustum* and it apparently has two or three generations a year in New York State. There remains much to be learned about the biological relationship of these two species, if they are specifically distinct, throughout the ranges of the species.

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PLATES

PLATE 1

ADULT

Head capsule

- 1 *Simulium* (*N.*) *vittatum* Zett.

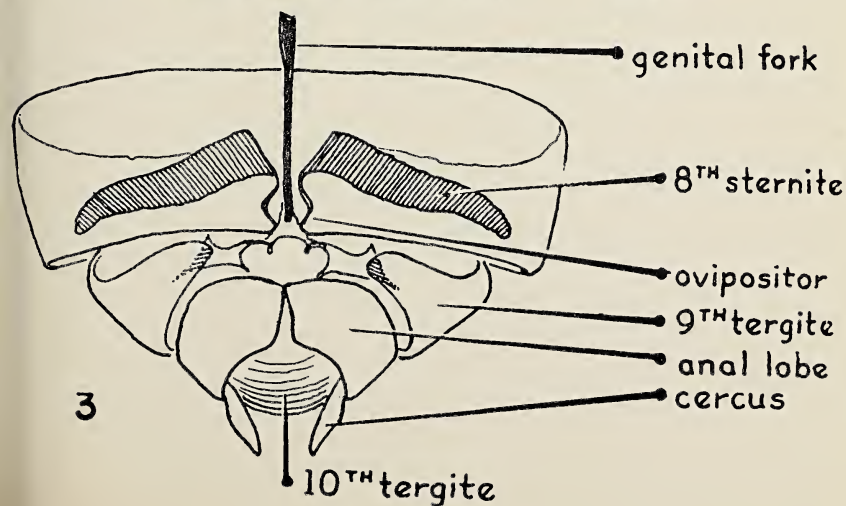
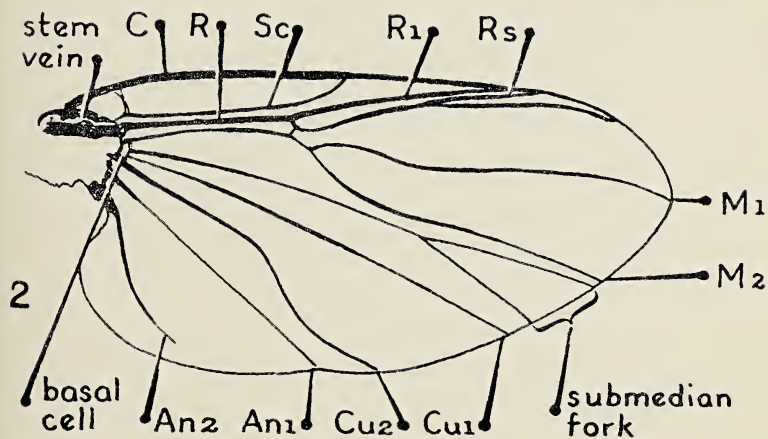
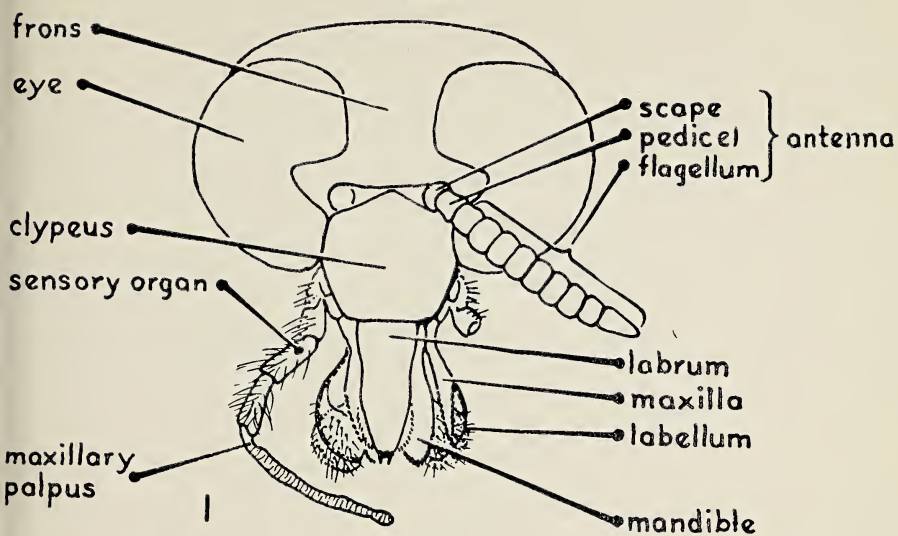
Wing

- 2 *Prosimulium hirtipes* (Fries)

Female terminalia

- 3 *Simulium* (*N.*) *vittatum*, Zett., ventral aspect

Plate 1



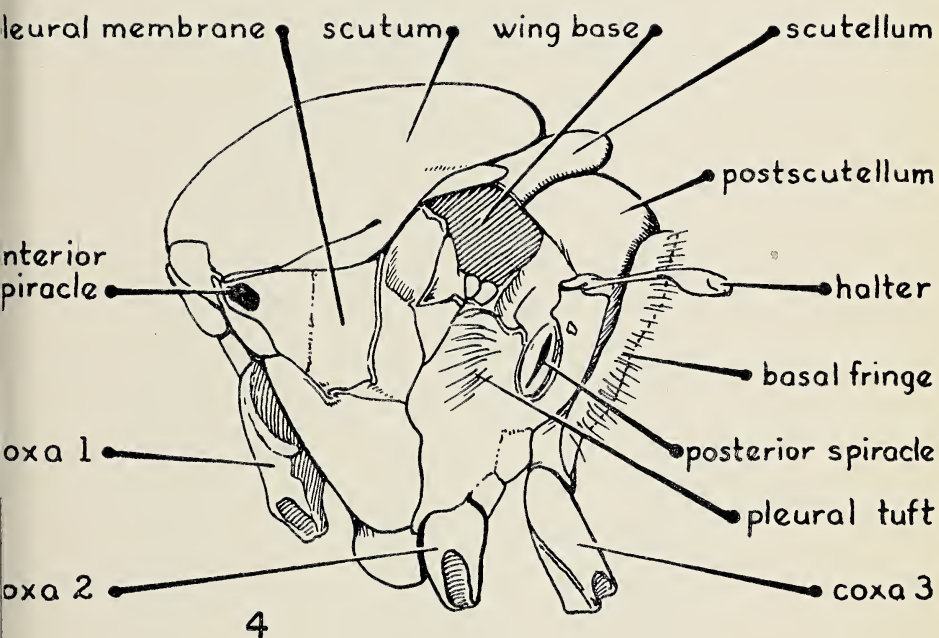
P L A T E 2

ADULT

Thorax

4 *Prosimulium magnum*, D. & S., lateral aspect

Plate 2



P L A T E 3

ADULT

Hind tarsus

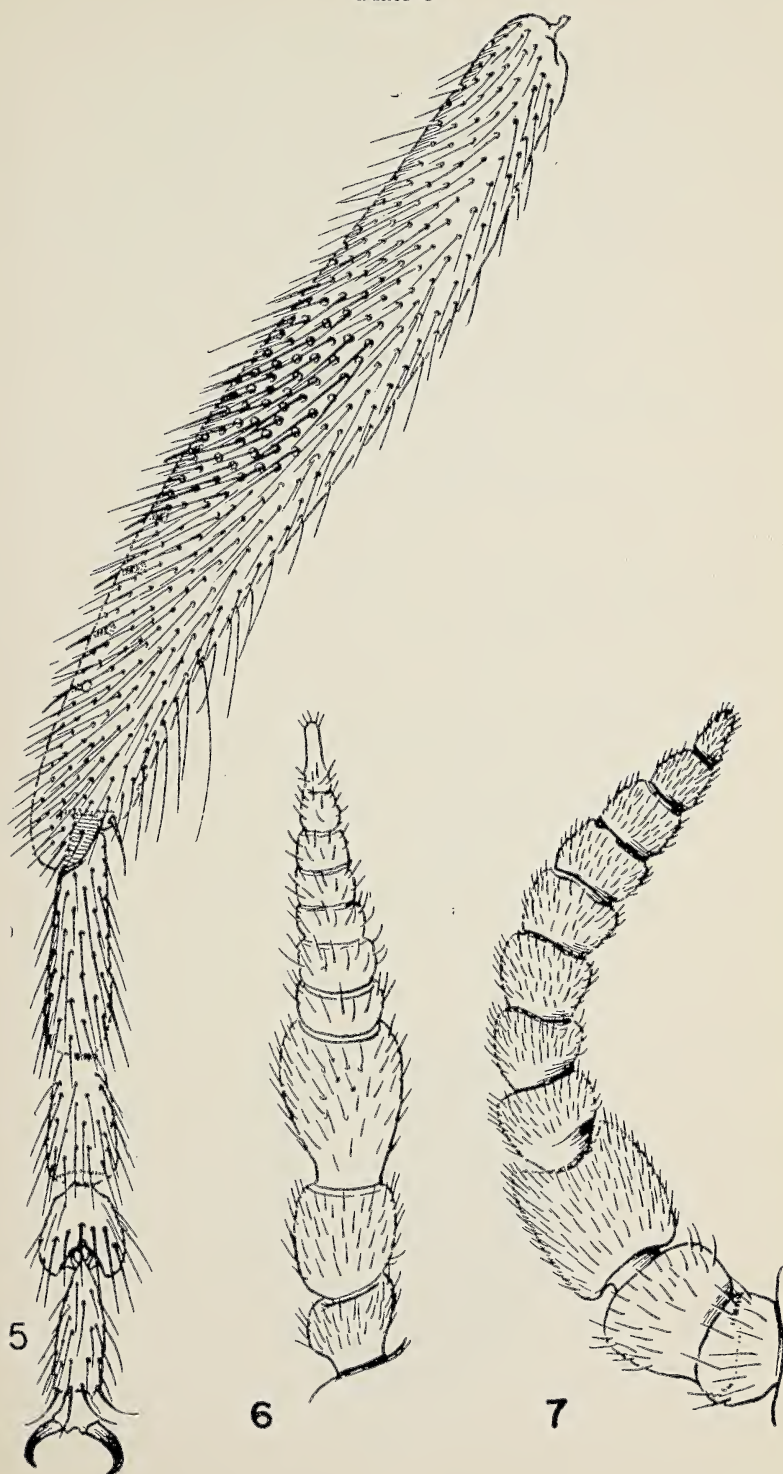
5 *Cnephia* (M.) *mutata* (Mall.)

Antennae

6 *Prosimulium magnum* D. & S., male

7 *Prosimulium magnum* D. & S., female

Plate 3



P L A T E 4

ADULT

Claws

- 8 *Simulium* (*S.*) *parnassum* Mall.
- 9 *Cnephia* (*C.*) *dacotensis* (D. & S.)
- 10 *Simulium* (*S.*) *corbis* Twinn

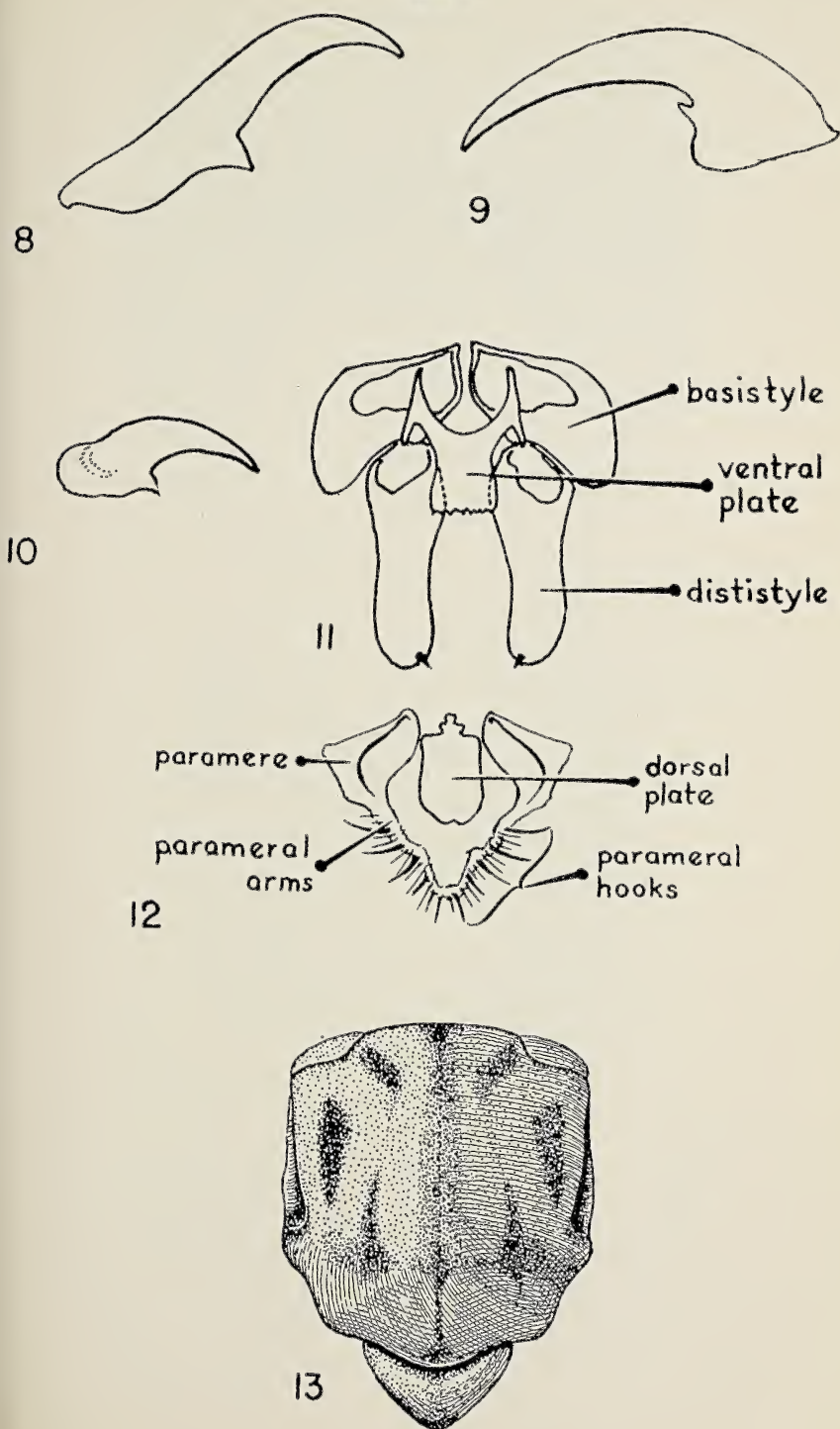
Male genitalia

- 11 *Simulium* (*S.*) *jenningsi* Mall., ventral structures
- 12 *Simulium* (*S.*) *jenningsi* Mall., dorsal structures

Thorax

- 13 *Simulium* (*N.*) *vittatum* Zett., dorsal aspect

Plate 4



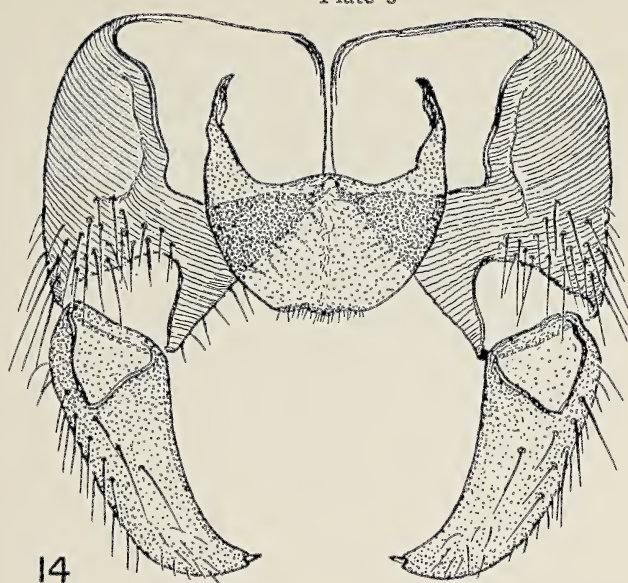
P L A T E 5

ADULT

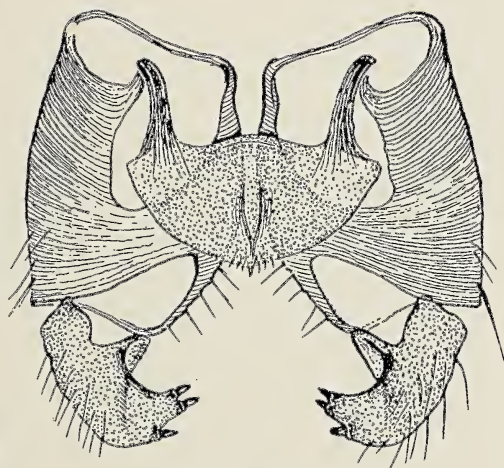
Male genitalia

- 14 *Cnephia* (C.) *dacotensis* (D. & S.)
- 15 *Prosimulium hirtipes* (Fries)
- 16 *Cnephia* (M.) *mutata* (Mall.)
- 17 *Twinnia tipplesi* n.g., n. sp.

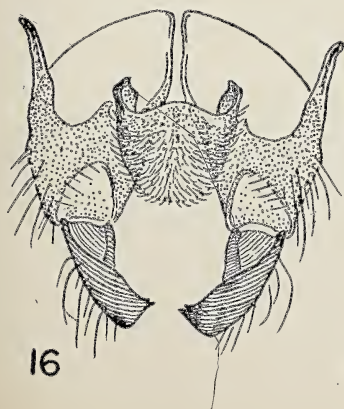
Plate 5



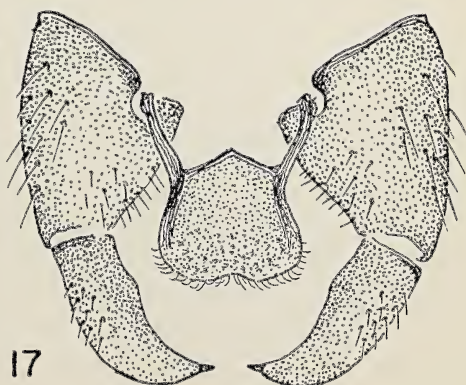
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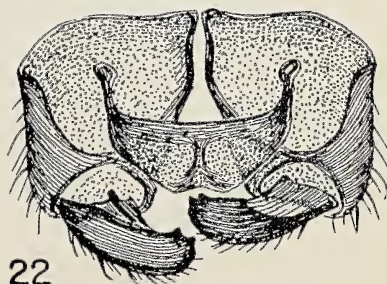
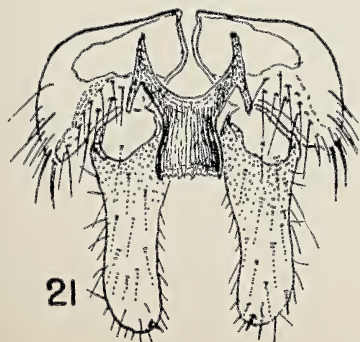
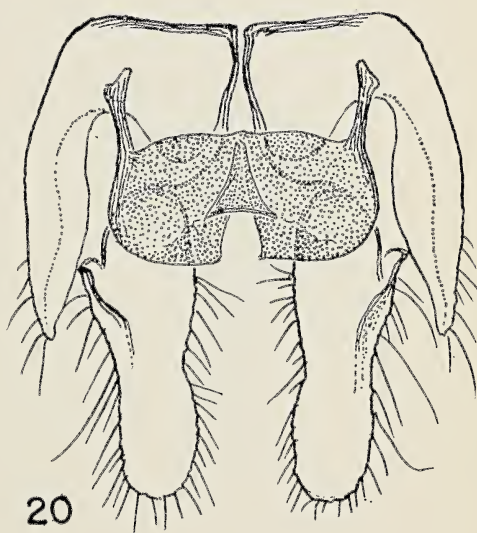
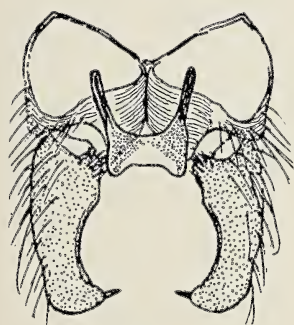
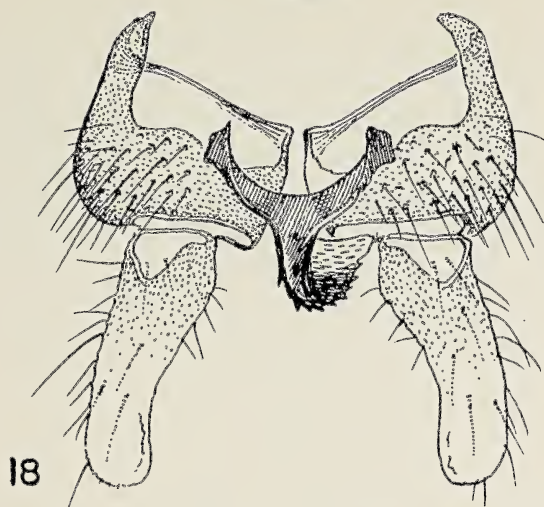
PLATE 6

ADULT

Male genitalia

- 18 *Simulium* (*S.*) *corbis* Twinn
- 19 *Simulium* (*S.*) *tuberosum* (Lund.)
- 20 *Simulium* (*S.*) *pictipes* Hagen
- 21 *Simulium* (*S.*) *jenningsi* Mall.
- 22 *Cnephia* (*E.*) *loisae* n. sp.

Plate 6



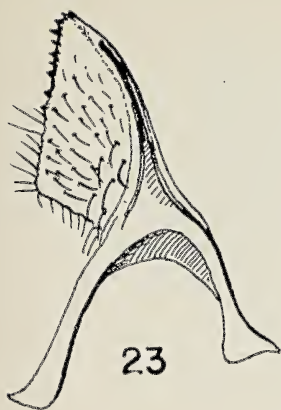
P L A T E 7

ADULT

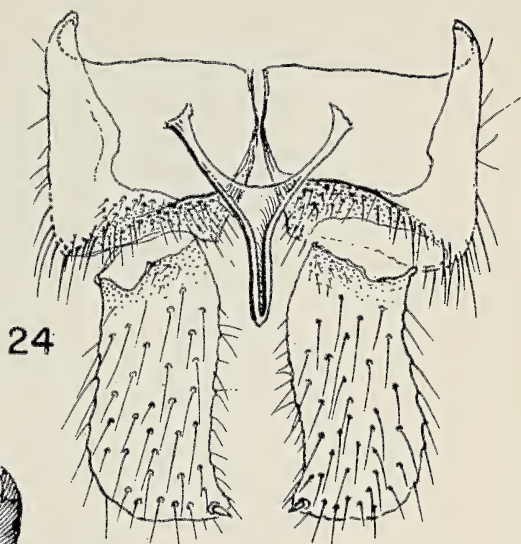
Male genitalia

- 23 *Simulium* (*S.*) *decorum* Walker, ventral plate
- 24 *Simulium* (*S.*) *decorum* Walker
- 25 *Simulium* (*S.*) *verecundum* n. sp.
- 26 *Simulium* (*S.*) *venustum* Say, ventral plate
- 27 *Simulium* (*S.*) *venustum* Say
- 28 *Simulium* (*S.*) *parnassum* Mall.

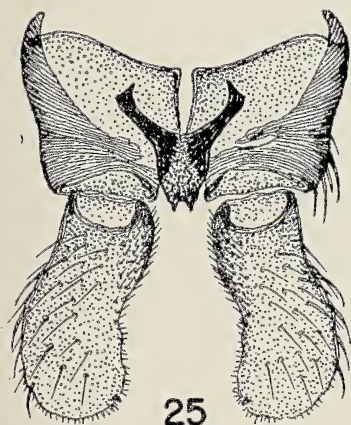
Plate 7



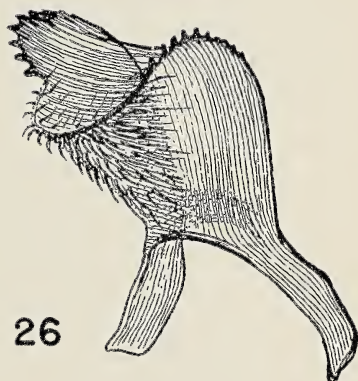
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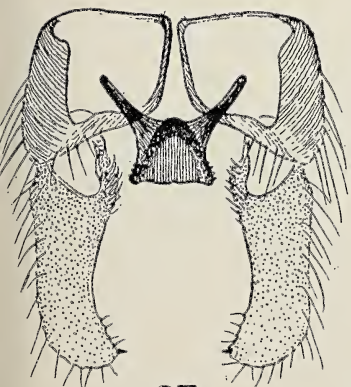
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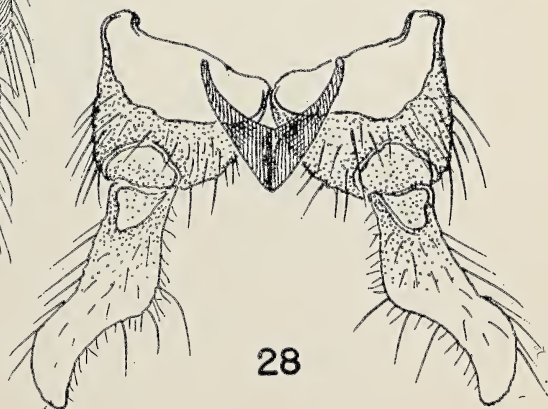
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28

PLATE 8

ADULT

Male genitalia

- 29 *Simulium* (*N.*) *vittatum* Zett.
- 30 *Simulium* (*E.*) *aureum* Fries
- 31 *Simulium* (*E.*) *pugetense* (D. & S.)
- 32 *Simulium* (*S.*) *fibrinflatum* Twinn

Plate 8

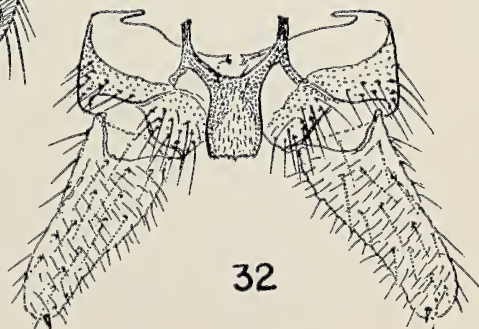
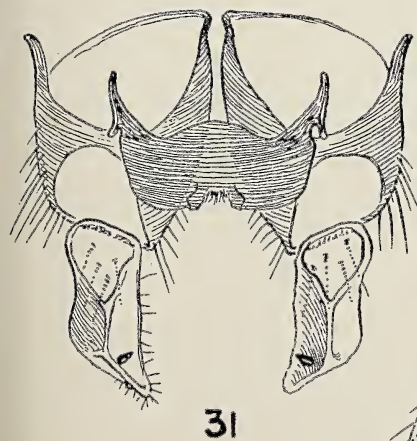
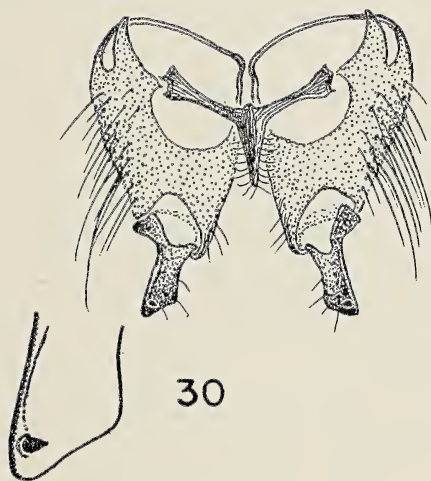
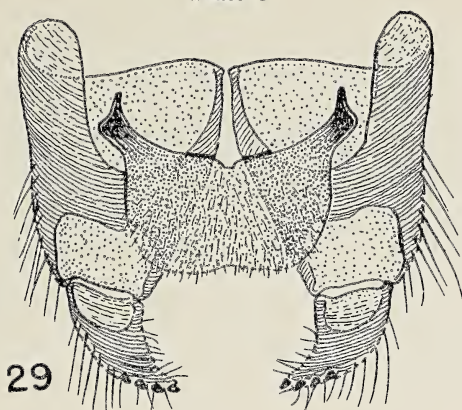


PLATE 9

ADULT

Female genitalia

- 33 *Twinnia tibblesi* n.g., n. sp.
- 34 *Prosimulium hirtipes* (Fries)
- 35 *Prosimulium magnum* D. & S.
- 36 *Cnephia* (M.) *mutata* (Mall.)
- 37 *Simulium* (S.) *parnassum* Mall.
- 38 *Cnephia* (C.) *dacotensis* (D. & S.)

Plate 9

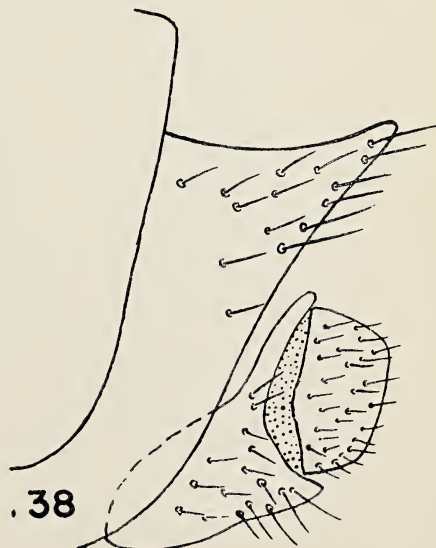
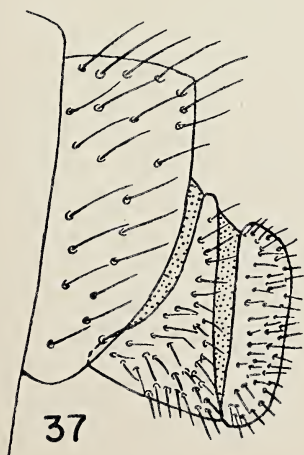
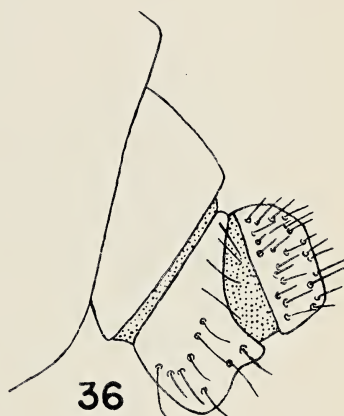
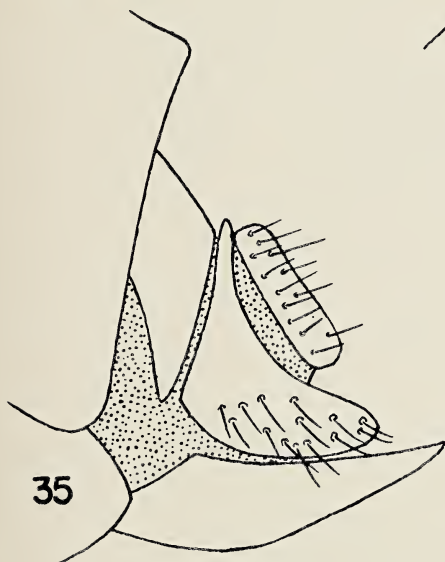
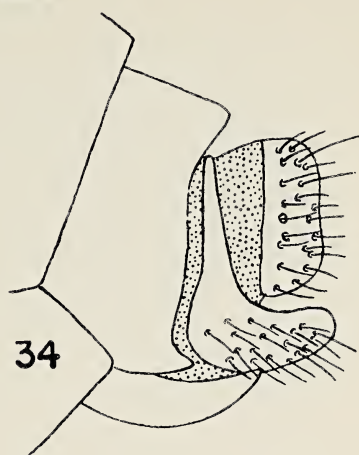
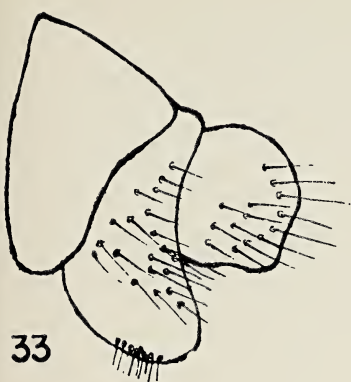


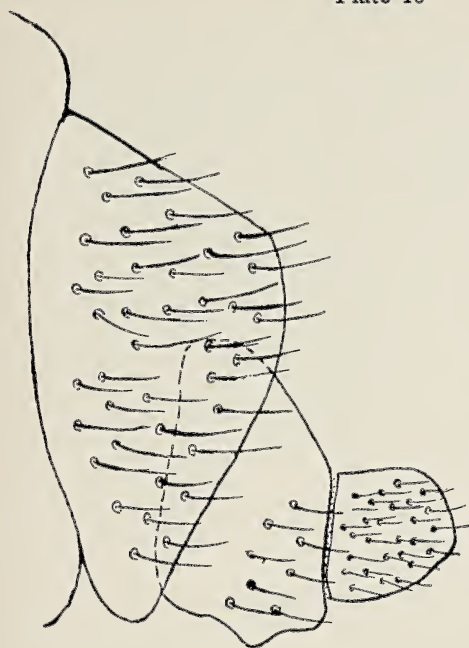
PLATE 10

ADULT

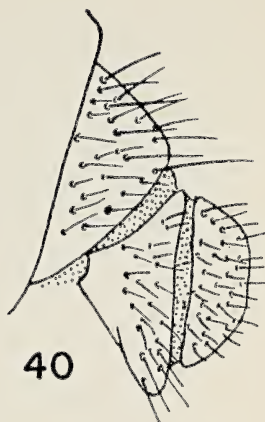
Female genitalia

- 39 *Cnephia* (*E.*) *loisae* n. sp.
- 40 *Simulium* (*S.*) *jenningsi* Mall.
- 41 *Simulium* (*S.*) *verecundum* n. sp.
- 42 *Simulium* (*S.*) *corbis* Twinn
- 43 *Simulium* (*S.*) *decorum* Walker

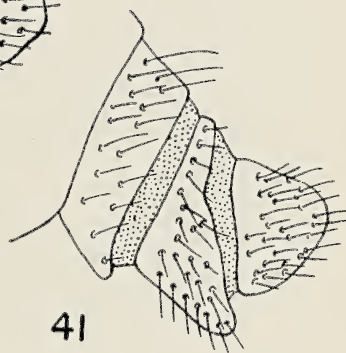
Plate 10



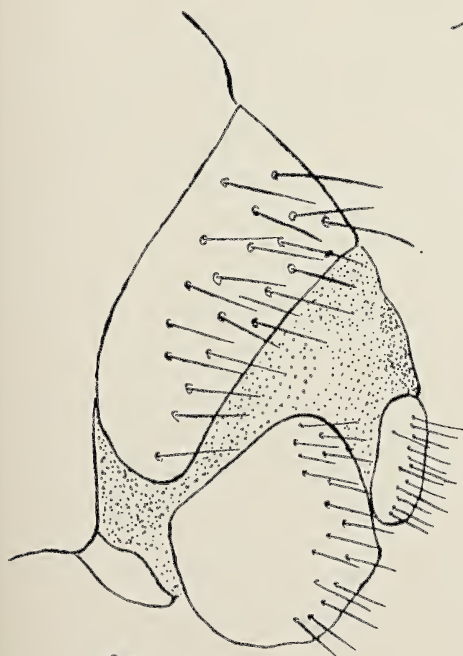
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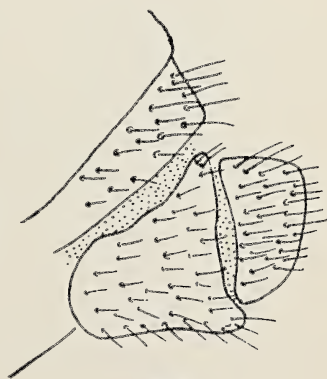
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42



43

P L A T E 11

ADULT

Female genitalia

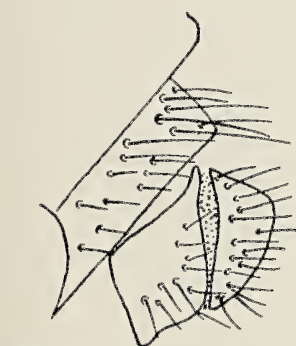
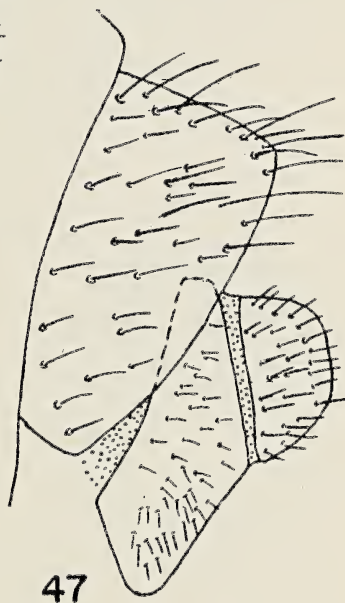
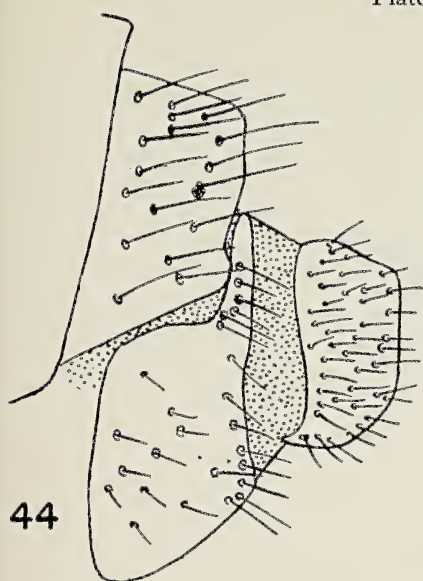
- 44 *Simulium* (*S.*) *pictipes* Hagen
- 45 *Simulium* (*E.*) *aureum* Fries
- 46 *Simulium* (*E.*) *latipes* (Meigen)
- 47 *Simulium* (*N.*) *vittatum* Zett.

PUPA

Respiratory filaments

- 48 *Simulium* (*S.*) *fibrinflatum* Twinn
- 49 *Simulium* (*S.*) *tuberosum* (Lund.)

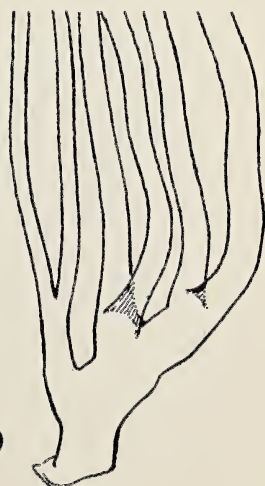
Plate 11



46



48



49

P L A T E 12

PUPA

Respiratory filaments

- 50 *Simulium* (*E.*) *croxtoni* N. & M.
- 51 *Simulium* (*S.*) *corbis* Twinn
- 52 *Simulium* (*S.*) *parnassum*, Mall., showing dorsal aspect thorax
- 53 *Simulium* (*S.*) *jenningsi* Mall.

Plate 12

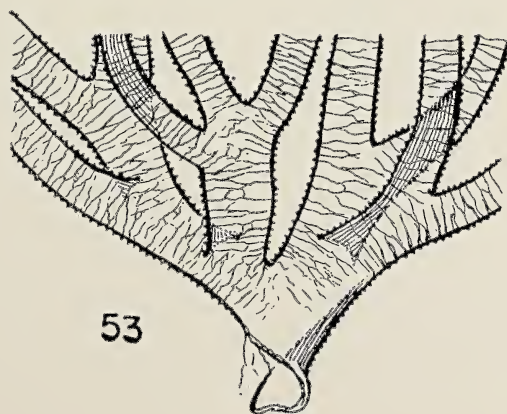
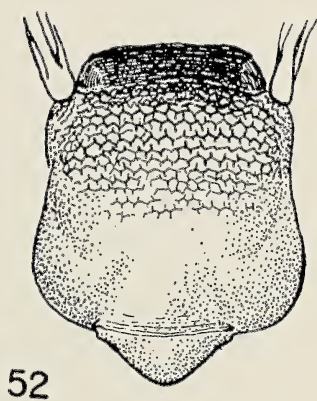
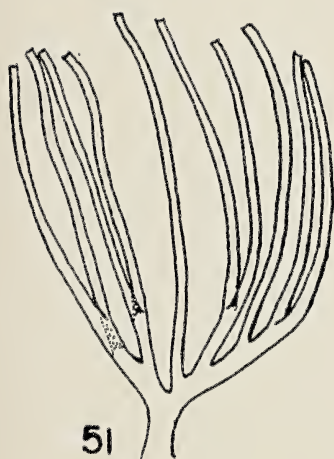
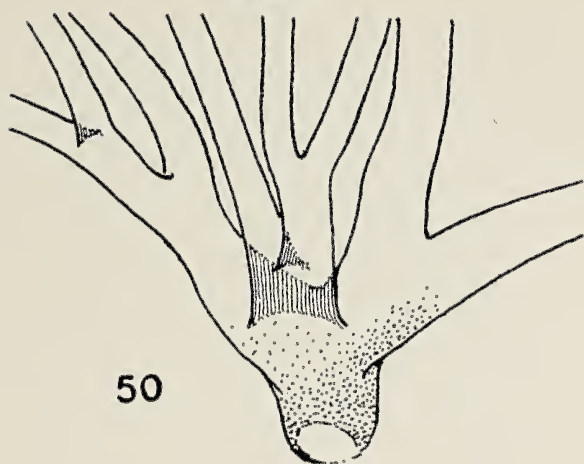


PLATE 13

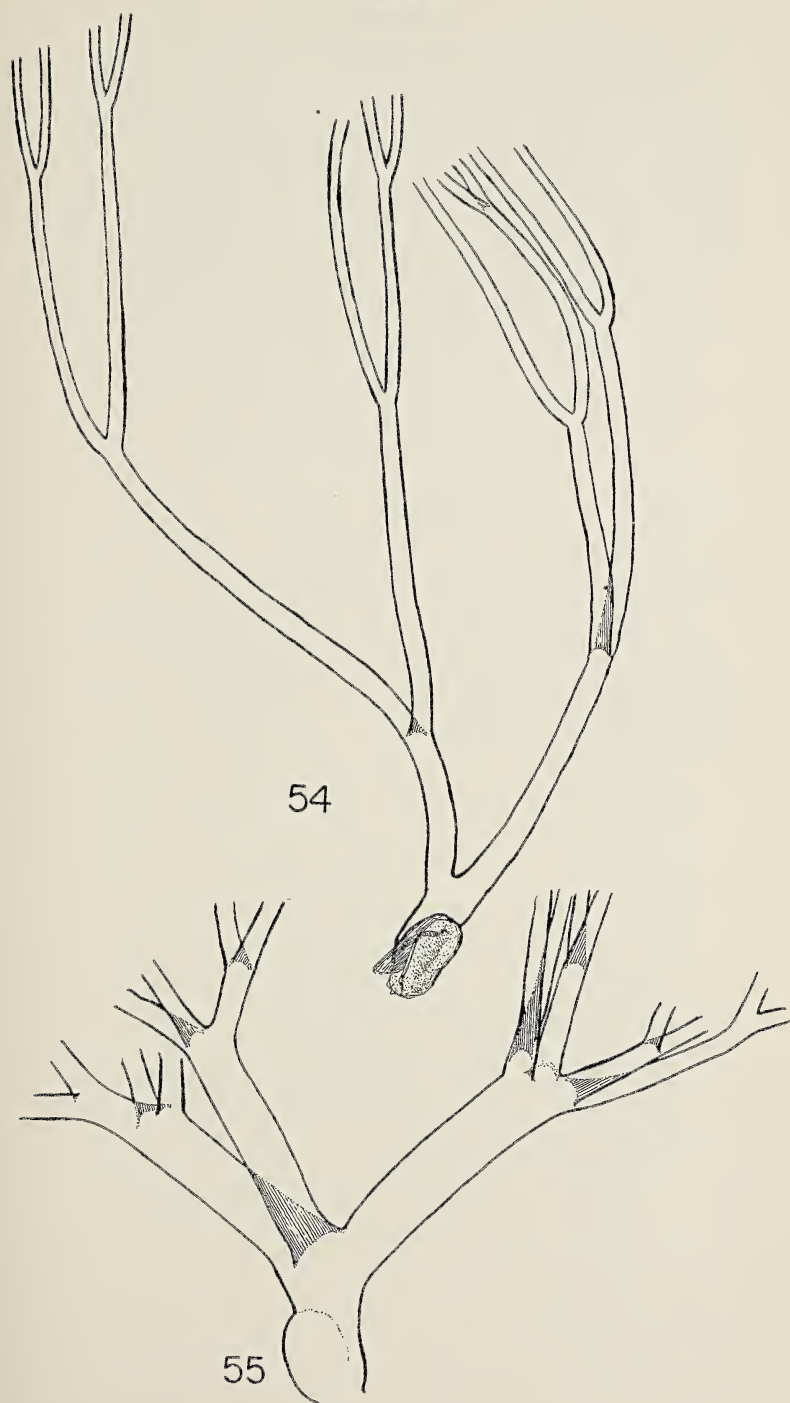
PUPA

Respiratory filaments

54 *Cnephia* (*M.*) *mutata* (Mall.)

55 *Twinnia tibblesi* n.g., n. sp.

Plate 13



P L A T E 14

PUPA

Respiratory filaments

- 56 *Prosimulium rhizophorum* n. sp.
- 57 *Prosimulium saltus* n. sp.
- 58 *Simulium* (S.) *pictipes* Hagen
- 59 *Simulium* (S.) *venustum* Say
- 60 *Simulium* (E.) *gouldingi* Stone
- 61 *Simulium* (S.) *decorum* Walker

Plate 14

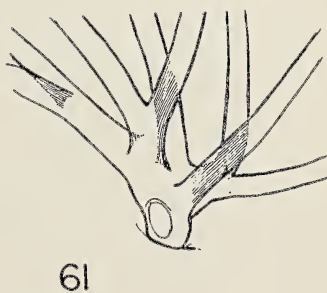
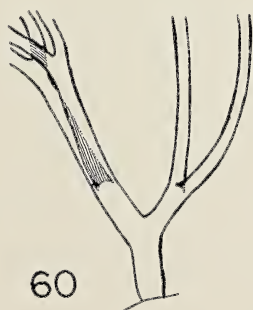
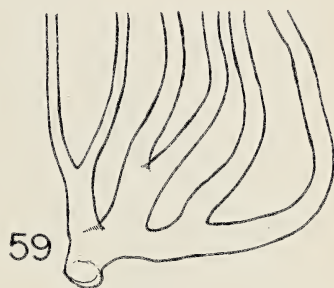
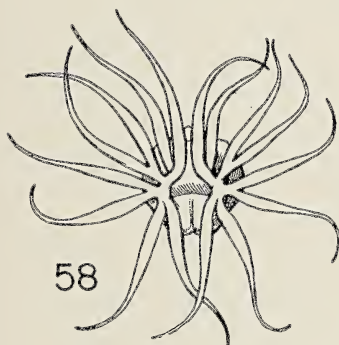


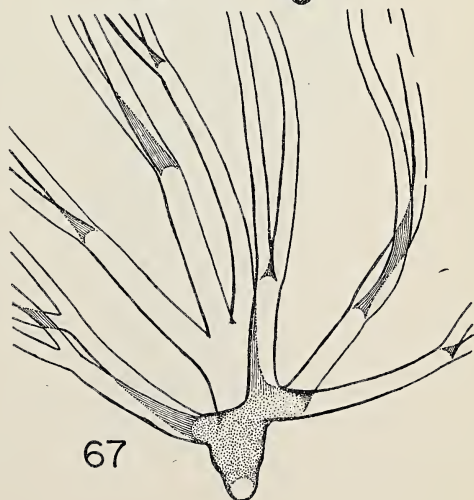
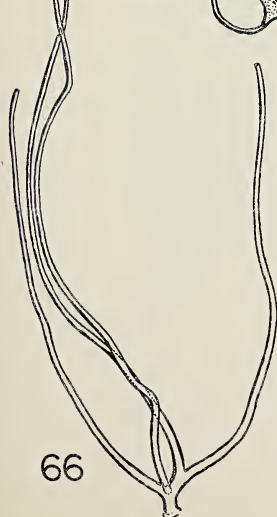
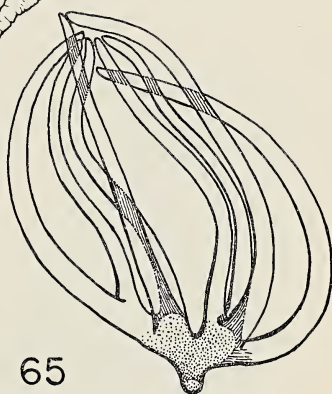
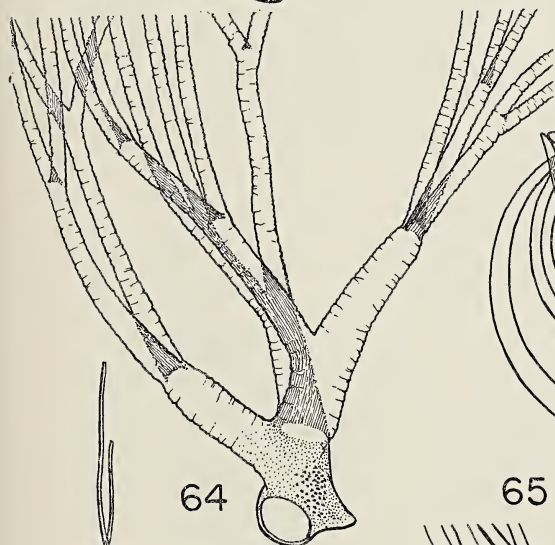
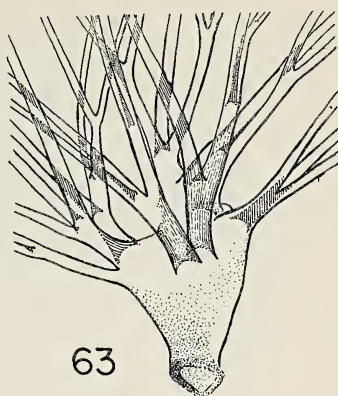
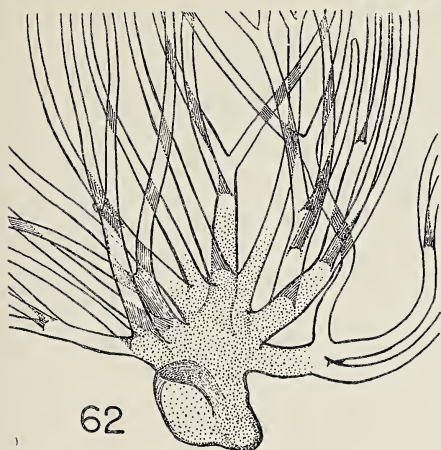
PLATE 15

PUPA

Respiratory filaments

- 62 *Prosimulium magnum* D. & S.
- 63 *Cnephia* (C.) *dacotensis* (D. & S.)
- 64 *Prosimulium hirtipes* (Fries)
- 65 *Cnephia* (E.) *loisae* n. sp.
- 66 *Simulium* (E.) *aureum* Fries
- 67 *Simulium* (N.) *vittatum* Zett.

Plate 15



P L A T E 16

PUPA

Respiratory filaments

68 *Simulium* (*E.*) *latipes* (Meigen)

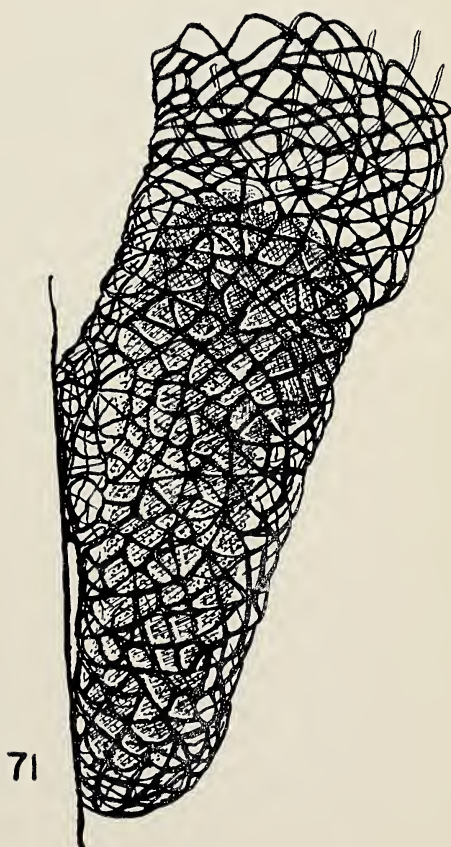
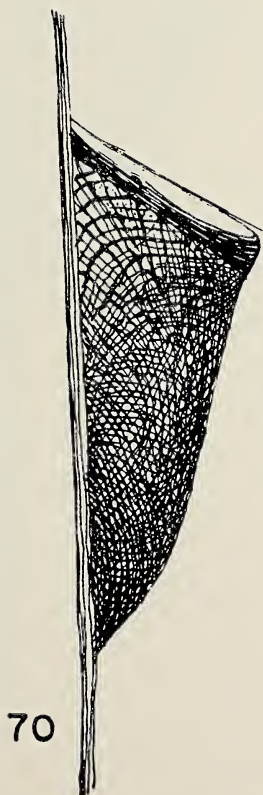
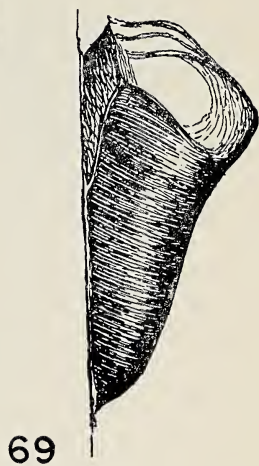
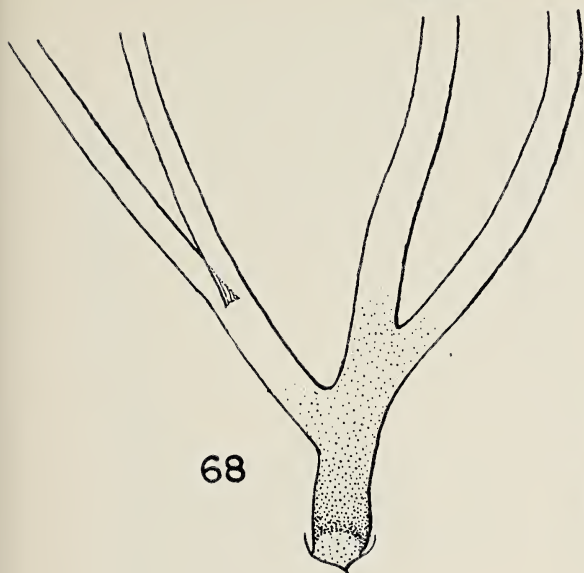
Cocoons

69 *Simulium* (*S.*) *jenningsi* Mall.

70 *Simulium* (*N.*) *vittatum* Zett.

71 *Simulium* (*S.*) *pictipes* Hagen

Plate 16



P L A T E 17

PUPA

Cocoons

72 *Cnephia* (*E.*) *loisae* n. sp.

73 *Simulium* (*S.*) *corbis* Twinn

74 *Simulium* (*E.*) *latipes* (Meigen)

Plate 17

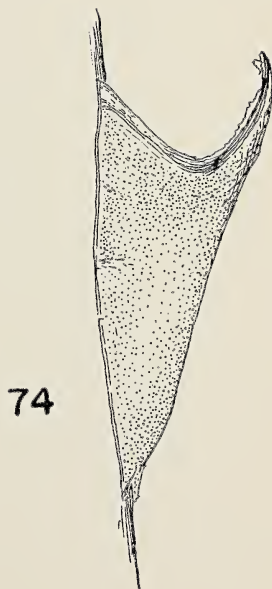
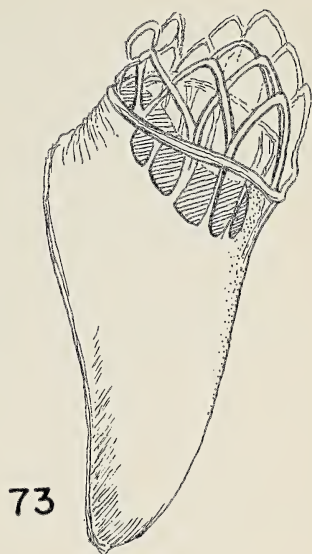
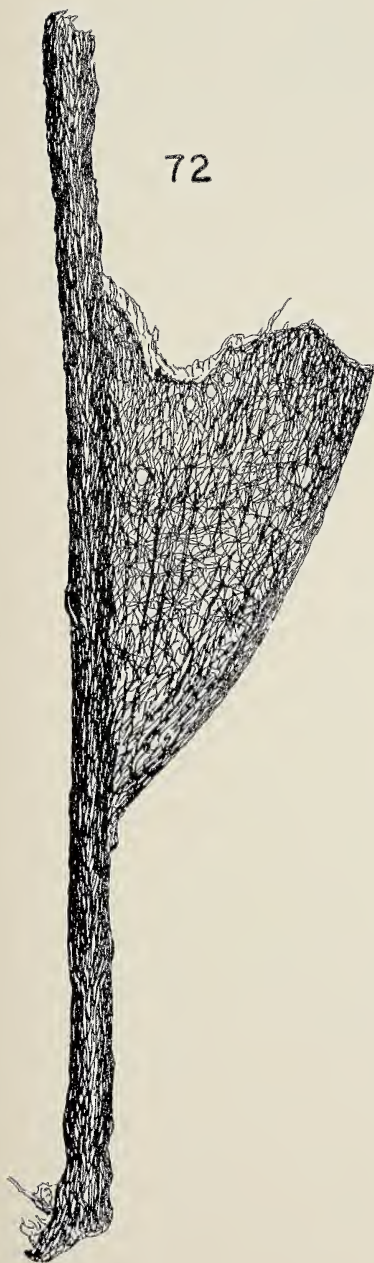


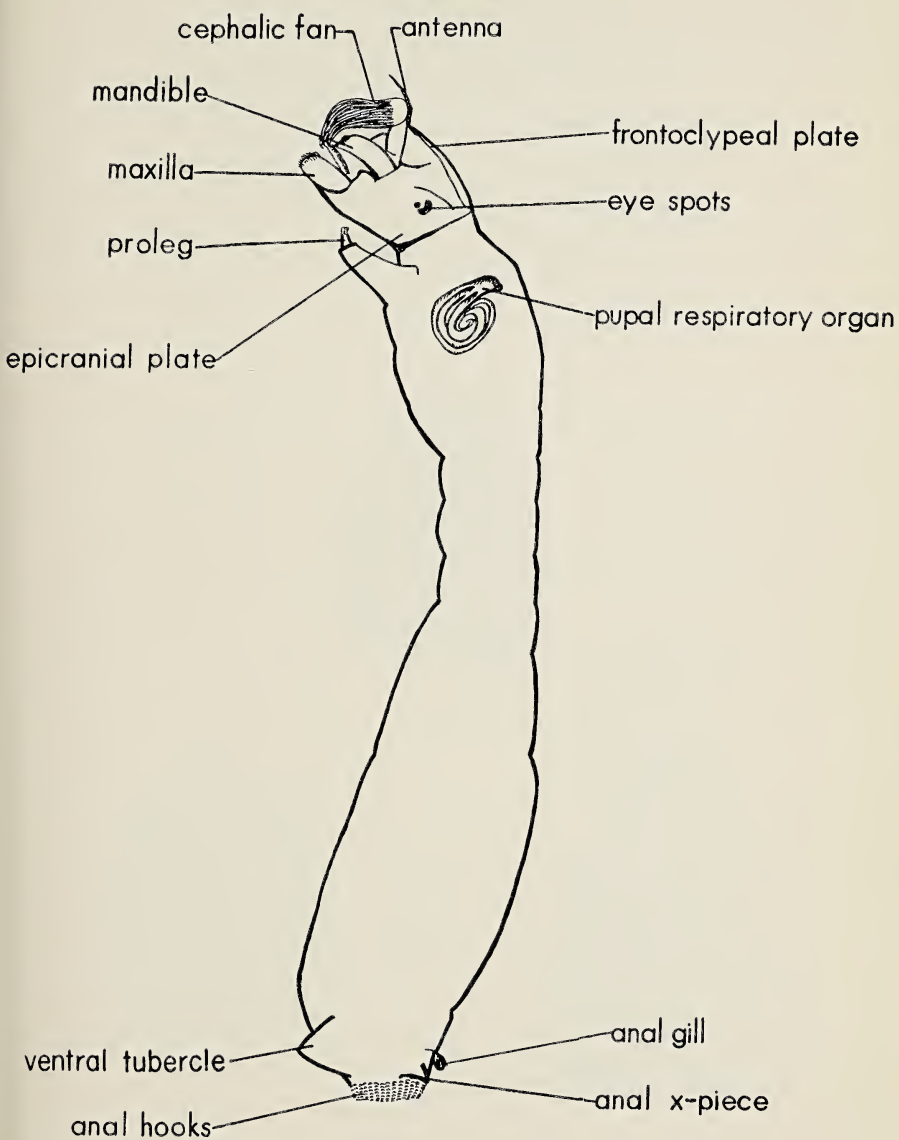
PLATE 18

LARVA

Habitus

75 *Simulium* (E.) *gouldingi* Stone

Plate 18



P L A T E 19

LARVA

Mandibles

76 *Twinnia tibblesi* n.g., n. sp.

77 *Simulium* (*N.*) *vittatum* Zett.

Head capsules

78 *Simulium* (*S.*) *venustum* Say

79 *Twinnia tibblesi* n.g., n. sp.

80 *Cnephia* (*M.*) *mutata* (Mall.)

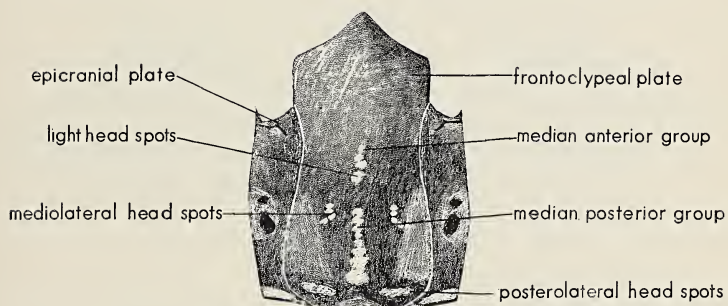
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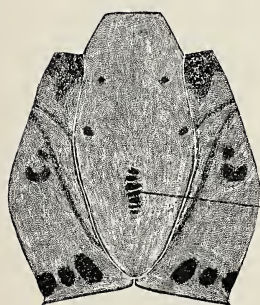
76



77



78



79



80

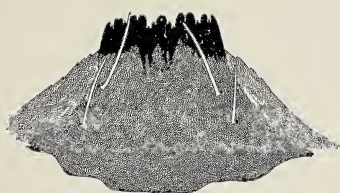
P L A T E 20

LARVA

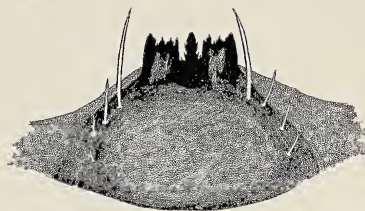
Submenta

- 81 *Twinnia tibblesi* n.g., n. sp.
- 82 *Prosimulium rhizophorum* n. sp.
- 83 *Prosimulium magnum* D. & S.
- 84 *Cnephia* (M.) *mutata* (Mall.)
- 85 *Cnephia* (E.) *loisae* n. sp.
- 86 *Cnephia* (C.) *dacotensis* (D. & S.)
- 87 *Simulium* (S.) *venustum* Say
- 88 *Simulium* (S.) *pictipes* Hagen

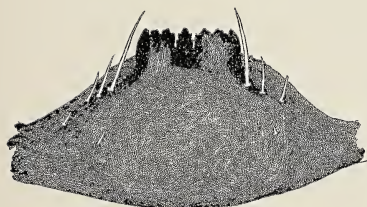
Plate 20



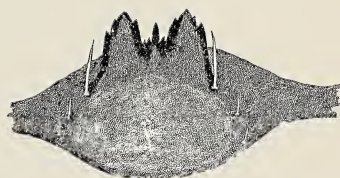
81



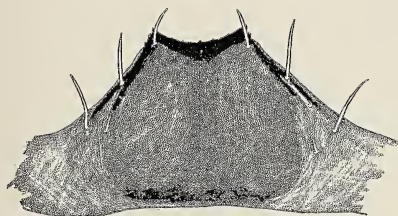
82



83



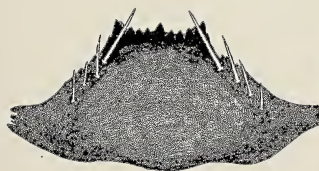
84



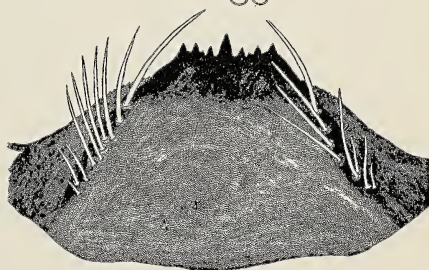
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88

PLATE 21

LARVA

Throat clefts

- 89 *Twinnia tibblesi* n.g., n. sp.
- 90 *Prosimulium hirtipes* Fries
- 91 *Cnephia* (*M.*) *mutata* (Mall.)
- 92 *Simulium* (*S.*) *venustum* Say
- 93 *Simulium* (*S.*) *tuberosum* (Lund.)
- 94 *Simulium* (*S.*) *parnassum* Mall.
- 95 *Simulium* (*N.*) *vittatum* Zett.
- 96 *Simulium* (*E.*) *aureum* Fries
- 97 *Simulium* (*E.*) *latipes* (Meigen)

Plate 21



89



90



91



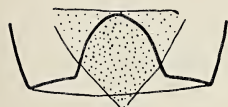
92



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94



95



96



97

PLATE 22

LARVA

Antennae

- 98 *Twinnia tibblesi* n.g., n. sp.
- 99 *Prosimulium hirtipes* (Fries)
- 100 *Prosimulium magnum* D. & S.
- 101 *Cnephia* (M.) *mutata* (Mall.)
- 102 *Cnephia* (E.) *loisae* n. sp.
- 103 *Cnephia* (C.) *dacotensis* (D. & S.)
- 104 *Simulium* (S.) *pictipes* Hagen
- 105 *Simulium* (N.) *vittatum* Zett.
- 106 *Simulium* (E.) *gouldingi* Stone
- 107 *Simulium* (E.) *pugetense* (D. & S.)

Plate 22



98



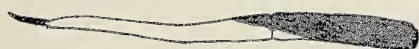
99



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103



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105



106



107

P L A T E 23

LARVA

Inner subapical margin of mandibles

- 108 *Prosimulium hirtipes* (Fries)
- 109 *Prosimulium rhizophorum* n. sp.
- 110 *Prosimulium magnum* (D. & S.)
- 111 *Cnephia* (E.) *loisae* n. sp.
- 112 *Simulium* (E.) *latipes* (Meigen)
- 113 *Simulium* (N.) *vittatum* Zett.

Anal cross-pieces

- 114 *Simulium* (S.) *decorum* Walker
- 115 *Twinnia tipplesi* n.g., n. sp.
- 116 *Prosimulium hirtipes* (Fries)

Plate 23



108



109



110



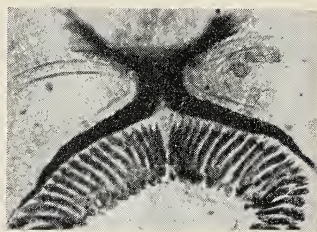
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BY

HUGO JAMNBACK

Entomologist

AND

D. L. COLLINS

State Entomologist

New York State Science Service



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The Control of Blackflies (Diptera, Simuliidae) in New York

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INTRODUCTION

Blackflies are among the most annoying insect pests in New York State, and in some localities they are the most important insect problem. The Town of Webb, which includes Thendara, Old Forge, Eagle Bay and Big Moose, is such a locality. The blackfly control program discussed in this bulletin was developed largely in the Town of Webb, and was made possible by the interest and support of its citizens.

According to Dr. Robert Lindsay, a physician of Old Forge, who has had many years' experience with the medical aspects of blackfly bites, some persons are nearly immune to them, while others suffer immoderately from a few bites. In most persons the bite produces a typical allergic reaction. Around the wound appears a pruritic urticarial wheal of varying intensity. With additional bites there is an increase in reaction. The whole area may become hot and edematous. At times the bites may raise large blisters.

Along with these local reactions, there is a general reaction which varies in intensity with the number of bites and the sensitivity of the individual. Headache, fever, nausea and adenitis may occur. This condition is usually of short duration, generally 48 hours or less. It leaves no after-effects except for the glandular enlargement, which subsides slowly.

Scratching of blackfly bites may cause skin infections ranging from a simple pustule to a deep cellulitis. In regions where the flies are abundant, children are frequently seen with a mass of purulent scabrous lesions of the scalp.

Early writers (Riley, 1887; Buck, 1888; Webster, 1904) have cited instances of blackflies causing human deaths.

In regions where livestock are of economic importance, blackflies cause injury more or less regularly if present only in moderate numbers. This injury may include loss of milk production, loss of weight, loss of work time, abortion and worry. At irregular intervals, blackflies become so numerous in some areas that they kill domestic animals. These outbreaks may occur for several years in succession in a given locality. According to Forbes (1912), when domestic animals are lightly attacked, the condition of the victim is not particularly alarming. The animal then apparently becomes partially immune to later attacks. But if heavily attacked, fatigue, failure of the appetite, drooping head, trembling, high fever and rapid pulse may occur. Later the pulse becomes feeble and death follows in a few hours. According to Schmidt (1916), animals attacked by large numbers of flies die within one or two hours, while less serious cases are characterized by loss of appetite, abortion, marked depression and blindness. Schoenbauer (1795) states that the nasal passages and bronchial tubes may become blocked by flies, causing death by suffocation.

The Mississippi Valley blackfly, *Cnephia pecuarum* Riley, was reported "bad," killing numerous animals, in 1861-64, 1866, 1868, 1872, 1873, 1874, 1881, 1884, 1885 and 1886 (Riley, 1887). Dyar and Shannon (1927) note that from the period following the Civil War *C. pecuarum* was not bad again until 1927. Bradley (1935) reported that 1927, 1928, 1931 and 1934 were bad blackfly years in Arkansas and Mississippi. In 1931 it was reported that 1000 mules in Arkansas alone were killed as a result of the attacks of this fly.

In the Balkans, the so-called Golubatz fly, *Simulium colombaschensis* (as *columbaczense*), takes a heavy toll of domestic animals. In 1923, a total of 16,474 domestic animals were recorded as killed in certain parts of Romania (Ciurea and Dinulescu, 1924). In 1934, a bad blackfly year, about 13,900 domestic animals were said to have been killed in Yugoslavia, Bulgaria and Romania (Baranov, 1935).

Undetermined species of blackflies killed cattle and severely injured sheep in parts of Germany in 1918, 1919 and 1920. Simuliidae are, at times, also pests of sheep in Australia (Roberts, 1940).

In Saskatchewan, successive outbreaks of the blackfly *Simulium arcticum* Malloch in 1944, 1945 and 1946 caused heavy livestock losses, killing 600 farm animals in 1946 alone (Rempel and Arnason, 1947).

Simulium griseicollae Becker has been reported as killing turkeys in northern Sudan (Garside and Darling, 1951).

In addition to the annoyance, illness and deaths which they cause directly by their bites, blackflies are known vectors of filarial and sporozoon pathogens in both man and animals. Tularemia has been experimentally transmitted by blackflies, and it is highly probable that they may be mechanical carriers of other bacteria such as anthrax bacilli, staphylococci and streptococci.

In New York State, the principal economic loss from blackflies occurs in resort and recreational areas, such as the Town of Webb. Here the presence of the flies may shorten the hotel season and reduce its income at various times during the summer. This is a serious economic consideration in an industry which depends for its existence on the income of the summer months. Businessmen in the Town of Webb reported that, following the first area-wide blackfly control program in 1948, there was a sharp increase in hotel reservations and a corresponding improvement in other business. Since at the height of a good season at that period the hotels of the region were doing a gross business of \$12,000 a day, it is readily apparent that the addition of a few days to the season, or full occupancy as compared to marginal operation, would alone justify a considerable outlay for blackfly control.

Blackflies have been a subject of concern to the State Entomologist's office for many years. In 1884, the State Entomologist, Dr. J. A. Lintner, reported on the biting habits of *Simulium venustum* Say (as *S. molestum*). Other reports originating in this office and treating blackflies to a greater or less extent include Aquatic Insects in the Adirondacks, by J. G. Needham and Cornelius Betten (1901); Aquatic Nematoceros Diptera, by O. A. Johannsen (1903); Blackflies and Other Biting Flies of the Adirondacks, by C. L. Metcalf (1932); and Control of Biting Flies in the Adirondacks, by C. L. Metcalf and W. E. Sanderson (1932).

While some of these early works advanced our knowledge of the biology and taxonomy of the Simuliidae, little was accomplished toward solving the control problem until the extensive studies of Dr. R. D. Glasgow culminated in the helicopter fogging program in the Town of Webb in 1948.

The success of the helicopter fogging stimulated continued research to discover less expensive methods of blackfly abatement. Several methods which have been studied and field-tested in the course of these investigations, including the helicopter fogging, are discussed in this bulletin, together with studies of the effects of these measures on other fauna.

Early in the work, it was found that much needed data on the biology of the species involved were lacking, and that their taxonomy

required thorough study. Studies of the biology and taxonomy of New York State blackflies were therefore made along with the control work. They are presented in a separate bulletin, entitled, *The Black Flies of New York State (Diptera: Simuliidae)*,¹ by Alan Stone and Hugo Jamnback.

The present bulletin is divided into four parts, as follows:

- 1 Area control of blackfly adults
- 2 Stream treatment for control of blackfly larvae
- 3 The effects of control measures on blackfly populations
- 4 The effects of control measures on other stream fauna and other wildlife

AREA CONTROL OF ADULT BLACKFLIES

In 1945, Dr. R. D. Glasgow, then State Entomologist, and the junior author, working with the early LaMer and early Todd fog generators (Glasgow and Collins, 1946), found that adult blackflies were readily killed by fogs made from 6 per cent solutions of DDT in No. 2 fuel oil. Further experiments showed that although local temporary control could be achieved by this type of fogging, the lack of suitably located roads not only made many properties inaccessible, but also made area control with truck-mounted machines alone virtually out of the question in most parts of the Adirondacks.

The helicopter, with its maneuverability and ability to fly slowly proved to be a most effective instrument for regional fogging. The downdraft from the rotor at a cruising speed of not more than 10 miles an hour forced the fog down through the forest canopy and caused it to spread out along the forest floor close to the ground (fig. 1). The fact that any small open field could be used for landing made the helicopter particularly useful in mountainous, heavily wooded areas.

HELICOPTER FOGGING IN 1948

Apparatus

A Bell helicopter was equipped with two Todd fog heads, one attached at the end of each of the exhaust stacks, which had been

¹ The common name applied to the Simuliidae appears in the literature variously as "black-fly," "black fly," and "blackfly." A literal interpretation of the principles suggested by the Committee on Common Names of the Entomological Society of America appears to imply the spelling "black fly," and this is the usage followed by Stone and Jamnback in their Bulletin, which deals with the taxonomy and biology of the group. However, it was found that in dealing with the general public the spelling "blackfly" was preferred, especially in a region where other, nonsimuliid "black" flies (e.g., *Sarcophaga aldrichi* and *Pollenia rudis*) are occasionally pests of public concern and subjects of wide publicity. The spelling "blackfly" was therefore adopted as most suitable for the present bulletin.

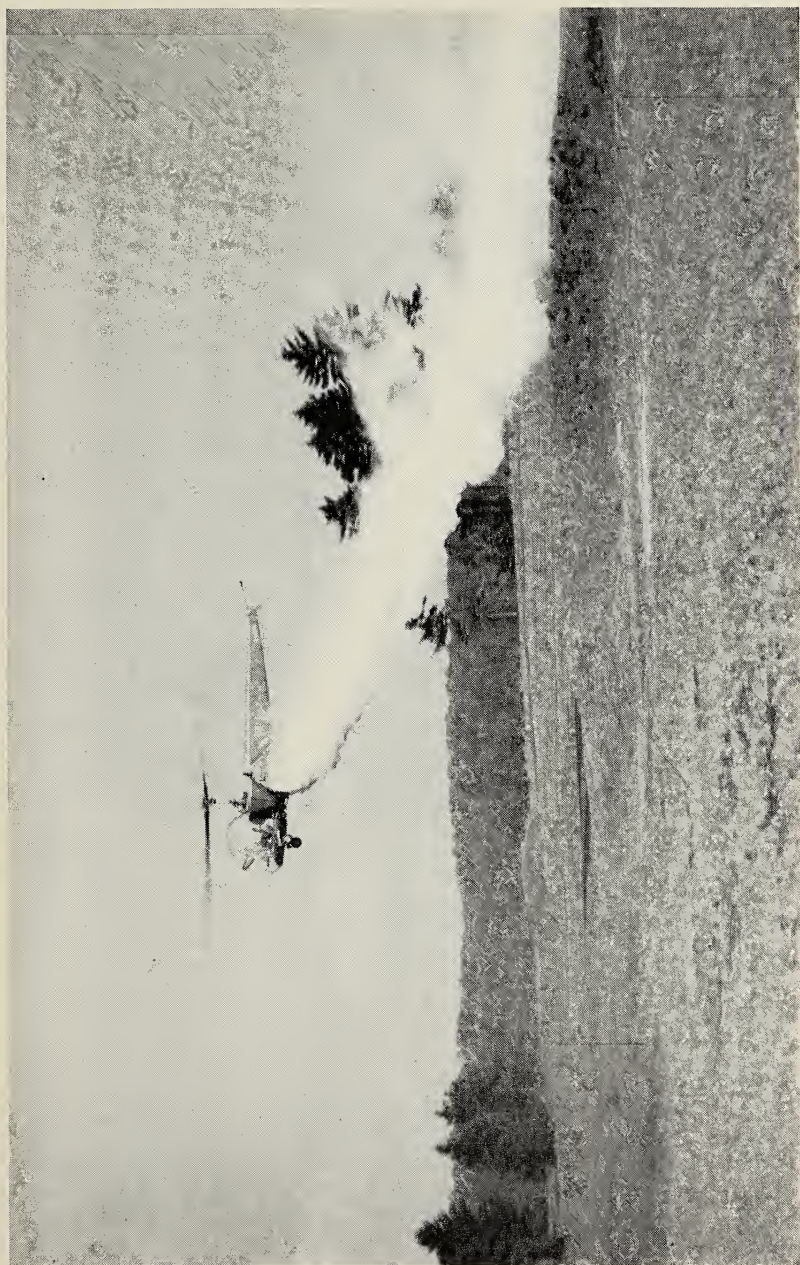


Figure 1. Helicopter fogging for adult blackfly control.

redesigned to accommodate them. The insecticide solution was contained in the twin side-hoppers that had been constructed for crop dusting, with appropriate modifications at the outlets.

A motor-driven insecticide pump with a relief valve forced the insecticide solution through feed lines which were furnished with graduated needle valves that could be set to supply, within limits, any desired number of gallons per minute to the fog heads. Electrical controls of the delivered volume were operated by buttons on the ship's control stick. The maximum output was about 50 gallons an hour. This produced a distinctly "wet" fog, although there were a sufficient number of small particles for effective drifting and penetration through the vegetation. Ordinarily, a medium dry fog was used.

For supplementary fogging, two Todd ground machines (Tifas) were available, and were used locally during intervals between helicopter foggings when flies were annoying (fig. 2).

Materials

A technical grade of DDT was dissolved in Sovacide F, a Socony-Vacuum product consisting of a mixture of petroleum fractions so combined as to retain a high DDT solvency, a high flash point, a high boiling point and optimum fog-producing qualities when injected into a hot air stream having a temperature of about 1500°F. The physical characteristics of this solvent are described in the paper, "Thermal Oil Fogs as Insecticides and Insecticide Carriers," by D. L. Collins (Advances in Chemistry Series No. 7, 1952; published by the American Chemical Society).

The insecticide solution was made up by dissolving 600 pounds of DDT in 440 gallons of the solvent, with continuous agitation. The result was an approximately 15 per cent DDT solution. The mixing was done in a 500-gallon trailer-tank, which was towed to convenient locations where the helicopter could replenish its supply of insecticide, or where drums could be filled from it for transportation by pickup trucks, for use by either the helicopter or the Tifas.

Method of Fogging

The helicopter flew at a height of about 60 feet, or about 10 feet above the treetops in the wooded sections, and the pilot endeavored to maintain a speed not exceeding 10 miles an hour. At this speed, with the downdraft from the rotor at about 26 miles an hour, the fog hit the ground about 100 feet behind the ship. Even in the densely wooded areas the fog was driven to the ground, where it spread out and either hung in or drifted through the vegetation.

The helicopter was able to cover up to 500 acres in a three-hour flight day. For the period June 1 through June 25, 1948, there were only four days when no fogging was done. All the routine fogging was done in the early morning or early evening hours.

Plan of Operations

For convenience, the areas to be treated were divided into four distinct plots, as shown on the map (fig. 3). The same plan was followed in 1949 and 1950, but the most detailed observations were made the first year, in 1948.

The four control areas, which together comprised about 4000 acres, are characterized as follows:

A **The "critical control area."** This plot included the villages of Thendara and Old Forge, the population centers of the Town of Webb, comprising about 1500 to 1700 acres. Located mostly on flat land, it was bounded on the north by the middle branch and a portion of the north branch of the Moose River; on the east by "the narrows" above the Old Forge dam; well closed off on both north and south by high ridges. This entire inclosed area was called the "critical control area" because it was decided to treat it as often as necessary to suppress the flies, whereas the other sections were to be treated only when their turns came in the schedule.

The helicopter made complete coverages of the critical control area on June 1st and 2d, June 15th and 16th, and June 24th, 25th and 26th. The area that was fogged extended a maximum of one mile north and northwest of the Thendara golf course, which is on the western edge of Thendara; and one-quarter to one-half mile in all directions beyond the outer streets of the villages. In addition, the helicopter made extra passes around the edges of the villages ("peripheral fogging"), usually concentrating along the railroad, golf course and river in Thendara, and along the river to the dam and back along the South Ridge in Old Forge, on June 6th, June 12th, June 18th, June 19th, June 20th and July 1st. On these peripheral foggings, the fogs usually spread along the ground so that it reached most parts of the populated sections. The truck-mounted Tifa also made peripheral foggings on May 31st, June 8th, June 10th, June 11th and June 14th, and one complete street-by-street fogging on June 3d.

In all, 600 gallons containing 780 pounds of DDT were discharged by the operations from both air and ground together in the critical control area. These amounts were probably in excess of the amounts actually needed, since on several occasions, the peripheral foggings were merely discharges of excess material as the helicopter was brought

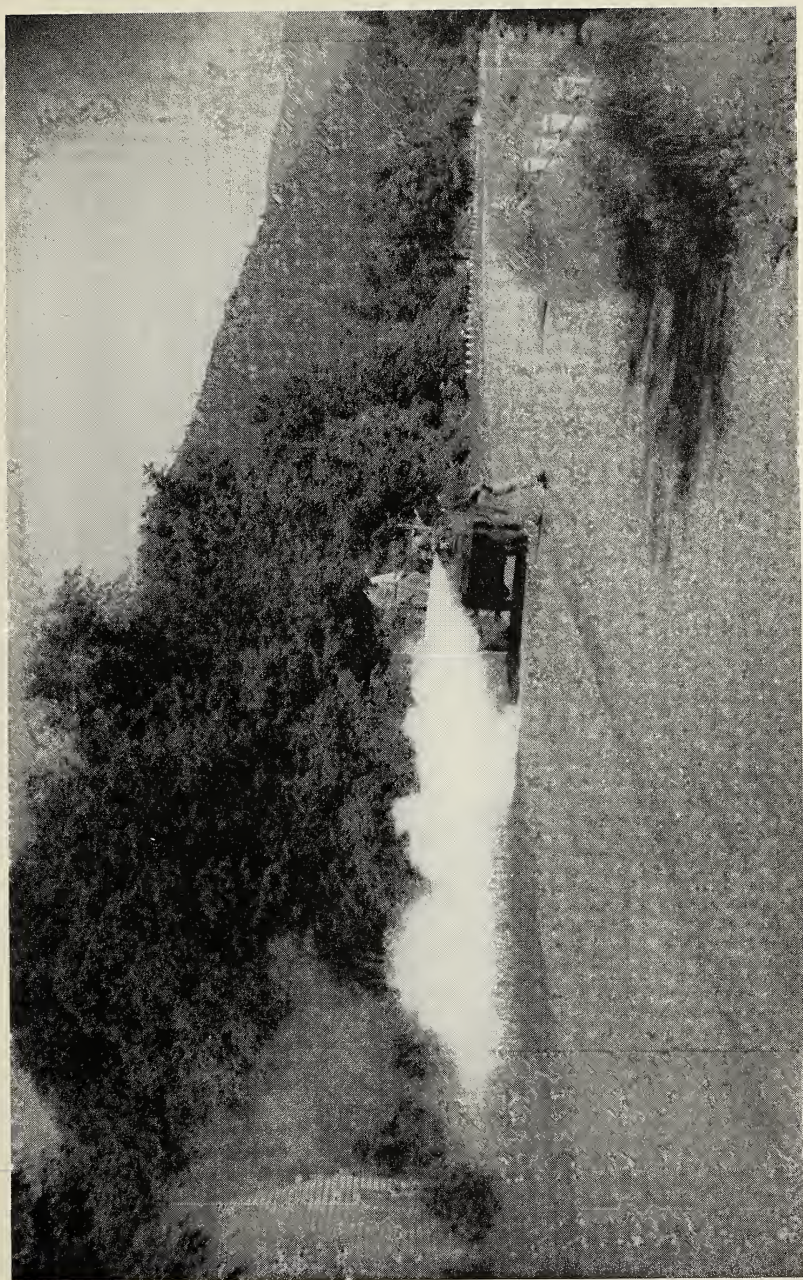


Figure 2. Truck-mounted fog generator operating along highway.

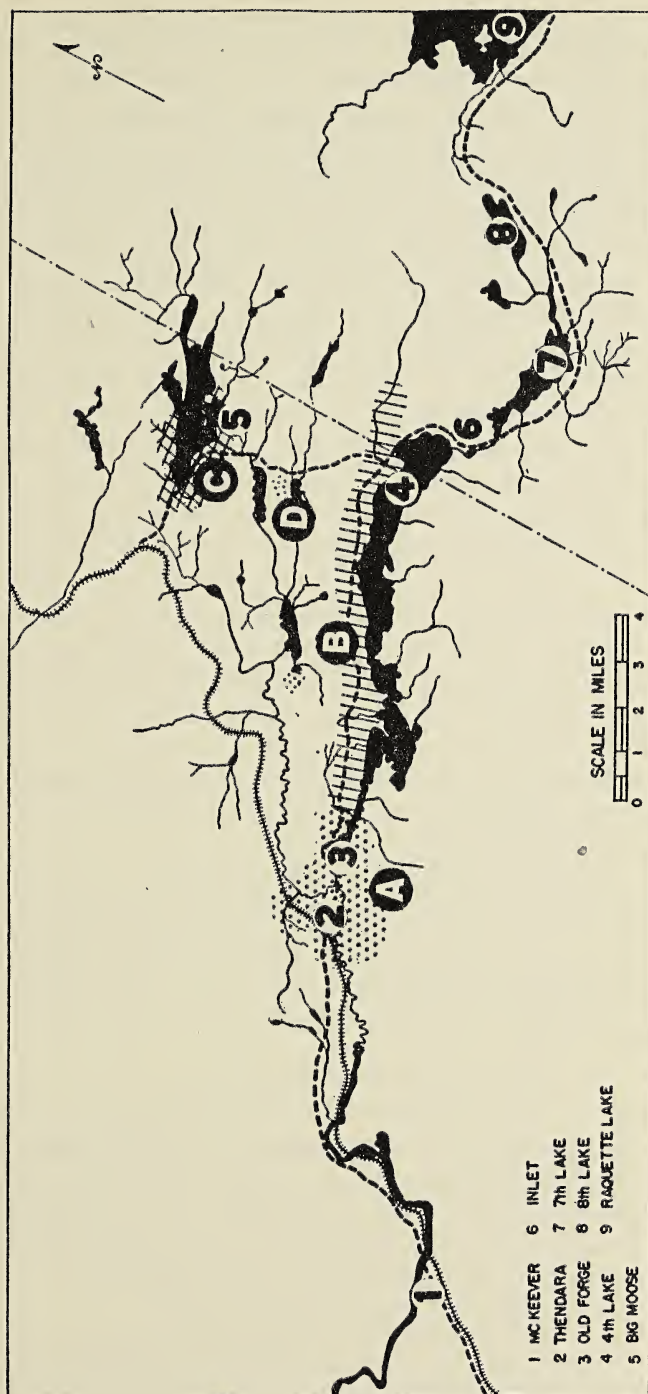


Figure 3. Map showing sections fogged by helicopter in 1948, in Town of Webb. See pages 14 and 18 for description of areas indicated by letters A, B, C and D.

back to the town garage for the night, and the ground machine was used on the slightest evidence that there were flies anywhere in town.

B North Shore of Fulton Chain in the Town of Webb, that is, along Fourth Lake from Old Forge to Eagle Bay. This sector is a narrow strip of land about eight miles long made up of large private properties, including hotels. It is bounded on the north by a high ridge including Bald Mountain, broken on the northeast by the narrow Eagle Creek valley; on the south by the Fulton Chain Lakes, and closed off on the west by a ridge which approaches First Lake east of Old Forge. At only two points is this naturally circumscribed area more than half a mile wide, that is, more than half a mile from the ridge to the lake.

C Big Moose Lake area. This comprised a series of large hotel properties with an aggregate of about 600 acres to be fogged. On the east and west and on the south shore, the mountain barriers were some distance from the treated zones. The Big Moose Lake section presented a special problem. It was the last of the three principal areas on the helicopter schedule. In the regular routine, the helicopter fogging in that area would have begun on June 6th or 7th. An accident to the helicopter on June 7th held up operations for several days, and it was not until June 12th that the fogging at Big Moose Lake could begin. By that time, all the Big Moose properties had reported "bad" fly conditions. Truck-mounted Tifa operations had given only very temporary relief.

D Isolated properties with no well-defined natural boundaries. These sites were fogged only on the third round, and included one hotel property and two summer camps.

The first round by the helicopter required six days, not counting an included period of four days when there were no operations. The dates of treatment were June 3d, 4th, 5th, 6th, 7th, and June 12th. The second round was completed in five days, June 17th, 18th, 19th, 20th and 21st. The third round required only three days, June 26th, 27th and 28th.

Results of Preliminary Tests

Observations of caged blackflies under field conditions showed that flies in any situation where the fog penetrated were killed. Flies that were hidden beneath dead leaves on the ground, or similarly protected, were not affected. It should be remembered that in these experiments the flies were confined in the protected locations and could not fly out and into the denser fog as unconfined flies were likely to do.

Results of the Regional Fogging

The effectiveness of the control operations was evaluated in two ways: (1) Project personnel made counts of the numbers of annoying

blackflies inside and outside of the control areas. (2) Residents of, travelers through and visitors to the region were questioned about the abundance of blackflies inside and outside of the control areas.

1 **Information from trained observers.** During June, after the first foggings, 52 separate observations and counts of flies were made by project personnel at 10 different locations on 20 different days in Old Forge, and 26 separate counts were made at the Thendara golf course. These do not include counts made during or immediately after an operation. Residents and others who were questioned frequently used expressions such as "bad" or "very bad" to describe high levels of fly abundance. It was found that these terms could be roughly correlated with actual counts, a count of more than 20 flies being rated as "bad." Since the descriptive terms are more vivid and, when considering a cloud of insects, just about as precise, they are occasionally used in this report. Since only annoying specimens were counted by project personnel or observed by casual observers, the species involved were presumably *Prosimulium hirtipes*, *Simulium venustum* and *S. tuberosum*.

A "count," in the fogging experiments, was originally the number of flies that could be swept into a net in one minute from around the face and head of the observer. Later, the method was changed to the number that could be counted around the head after the observer had stood, or walked around slowly, for two minutes. When the flies were numerous, estimates were made. On the same dates as the counts in Old Forge, and as close as possible to the same times, observations were made outside of the control area. These points were located four and six miles west of Thendara; at Rondaxe dam, Eagle Creek, Cascade Brook, Inlet, Big Moose Lake, Eighth Lake, Raquette Lake and Blue Mountain Lake. See map, Figure 3.

In the critical control area of Old Forge, 60 per cent of the counts were "no fly" records and an additional 15 per cent were counts of one or two flies only. In other words, 75 per cent of the counts indicated not more than one or two flies present; and there were no records of flies being "bad" at any time.

Not quite so good was the record of the Thendara golf course, which was in a rather unfavorable location in that several avenues of possible reinfestation converged there. Even at the golf course, however, only 8 per cent of the observations revealed conditions described as "bad," and there were none described as "very bad." Fifty per cent of the counts were records of "no flies" with an additional 19 per cent recorded as "one or two flies."

During the same periods, in check areas outside the critical control

area, a very different condition occurred. Eighty-four per cent of the 69 observations showed flies to be "bad," or "very bad." Only eight observations were in the "one or two flies" or "no flies" category.

2 (a) **Information from residents.** Residents of Old Forge were uniformly enthusiastic about the absence of flies in the village. Among the points most often mentioned were that children could play out of doors all during the month of June without being molested by blackflies; that the bathing beach was well populated by swimmers and sunbathers; that persons could engage in out-of-door activities such as golf, tennis and baseball, and in work such as gardening, grass cutting, wood cutting and hanging up laundry without being attacked by flies. During the same period flies were numerous and annoying in adjacent communities, and had been so in Old Forge in previous years.

(b) **Information from campers and other visitors.** On June 22d, two canoeists were interviewed as they landed at Eighth Lake Campsite. They did not know of the control program. They had started at Old Forge and had paddled up the Chain to Eighth Lake, camping overnight on the Hollywood Hills property on First Lake. They reported that there were no blackflies until they left Fourth Lake at Inlet (the end of the control area). Thereafter the flies were annoying, especially around Sixth and Seventh Lakes. After completing their trip, one of them reported that blackflies were numerous along Brown's Tract Inlet, beyond Eighth Lake, at Raquette Lake and along the Raquette River.

On June 26th, 25 boys in 12 canoes, paddling from the dam at Old Forge down the middle branch of the Moose River to the junction at Thendara bridge, thence up the north branch toward Rondaxe—all in the control area—reported no blackflies from the dam to the Thendara bridge (first interview, middle of first day). They camped overnight near the Indian Rapids, in the midst of what, up to that time, had been one of the worst blackfly areas, and were interviewed the following day. They reported only two bites in the entire group. Many of them had not used any repellents; others had used them since they had always been customary in that region. At Rondaxe dam, up river three or four miles from the rapids, and outside of the control area, flies were very numerous during the same period.

Results Outside of Old Forge and Thendara

Conditions outside of the critical control area were more variable. Hotels which were in the center of the line of contiguous fogged properties on the north shore of the Fulton Chain experienced about four days of almost complete protection after a routine helicopter fogging.

Hotels at the ends of the north shore control area and those located on narrow portions of the lakes sometimes had only one or two days of relief, after which the flies came in again and the fly population built up.

Hotel properties which were surrounded or nearly surrounded by unfogged territory, required very thorough fogging, including special attention after the routine rounds, to suppress the flies, especially around the edges of the property.

In several of the isolated camps, which were fogged only on the last round, control was not accomplished where the camp lacked prominent natural boundaries. But in the one camp where an entire lake was included within its boundaries, and where the lake shore and a zone one-quarter to one-half mile deep around it were fogged thoroughly, satisfactory blackfly abatement was achieved.

Effects of the Fogging on Wildlife

During the operations, observations were made on the wildlife of the area, especially birds and fish, to determine whether they suffered any ill effects.

At one of the helicopter ports, where the lake front not only received the routine fogging, but was also fogged frequently when the helicopter took off and landed, more than two dozen perch, sunfish and golden shiners were taken by the project personnel on flies and bait by fishing along a broken dock. Other persons were often observed catching fish from the same places. At no time were any dead or ailing fish seen or reported. Birds were numerous and active in the area.

At a roadside bait and tackle stand in Thendara there were two open minnow tanks, each about ten feet square. The tanks were thoroughly fogged on each of the three routine helicopter coverages of the area, and several more times during the peripheral foggings; also several times by the Tifa. No ill effects were seen or reported.

A pond of about six acres surface area was fogged three times by helicopter and several times by the Tifa. Bullheads and shiners were common in the pond, but did not show any ill effects from the fogging. A minnow trap at the outlet of the pond did not trap any ailing fish.

Trout were caught regularly in a creek that was thoroughly fogged three times, and from two lake docks that were included in the same routine foggings.

At the end of the operations, on July 1st and 2d, several bass were caught just above Old Forge dam, which had been fogged perhaps more heavily than any other single site. Several others were caught just below the dam.

Discussion and Conclusions on the Area Fogging Operations

All available evidence indicated that satisfactory blackfly control or suppression was accomplished in the villages of Thendara and Old Forge by the fogging operations described above. Owing to the conditions under which the work was done, much of the evidence had to be circumstantial, but none of it was contradictory.

It was evident that to obtain blackfly abatement by area-wide fogging, the area must be either comparatively large and compact, with deep barrier zones which are just as thoroughly fogged as the center; or it must be closely bounded by very distinct natural barriers or hindrances to rapid infiltration of flies, such as a high ridge or a body of water several miles wide; and it must be fogged thoroughly and completely at short intervals, ranging from four to seven days, depending on the weather and the topography of the area.

It might be observed here that whether a given condition should be considered "good" or "bad" is a relative and highly subjective matter. An old resident of a heavily infested area might be satisfied with a 75 per cent reduction or less, whereas a "paying guest" might not be satisfied with anything less than virtually complete freedom from flies.

OTHER STUDIES OF ADULTICIDING FOR BLACKFLY CONTROL

Travis (1949) described treatment of one-half square mile plots with DDT thermal aerosol fogs, applied from the ground. Although applied under apparently nearly perfect conditions, the fog did not give a satisfactory kill.

Prévost (1948) reported that a fog generator, when used in small areas, afforded little if any relief. When 70 acres were treated some relief was noted for 24 hours. Some of his conclusions were based on the Town of Webb, New York, operation, at which he was an invited observer.

Goldsmith *et al.* (1949), using ground-operated spray equipment, treated two test plots of 118 and 130 acres respectively. A dosage of 0.35 pound of DDT per acre was applied, using a 5 per cent fuel oil solution. A reduction of 99.8 per cent in numbers of annoying blackflies was noted 24 hours after treatment. After 48 hours infiltration was noted and four days after treatment, counts were very high. When plots of one to two acres were treated, using knapsack sprayers to apply a dosage of two quarts per acre with a 30-foot swath interval, there was a temporary reduction in blackfly populations, but heavy reinfestation occurred within 15 minutes to an hour. Pyrethrum and pyrethrum-DDT aerosol bombs, DDT-nicotine and BHC smoke bombs were also ineffective in small areas.

Wilson *et al.* (1949), using a modified Besler fog generator, on two successive days fogged 64 acres, along a road front of .53 mile the first day and .7 mile the second. The calculated dosage was 0.21 pound of DDT per acre, from a 6 per cent solution of DDT dissolved in fuel oil and auxiliary solvent. During the treatments, an air movement across the road and into the area to be treated aided in the dispersal of fog, and good inversion prevailed. Blackflies were found to be annoying 15 hours after the first treatment and a great many were present immediately after the second treatment. In 10 experimental treatments, no satisfactory 24-hour protection was obtained, even with fronts up to one-half mile.

Twinn (1950, 1952) noted that fog machines "have definite value when used properly under suitable conditions," although his preliminary experiments were not entirely satisfactory.

Brown *et al.* (1950), noted that adult blackflies were killed by a DDT spray applied from aircraft at the rate of 0.165 pound per acre. Nineteen square miles were treated with 4.2 per cent DDT in fuel oil and auxiliary solvent. Swaths were flown 200 yards apart at variable heights, depending on wind velocity. Under these conditions, control inside of the control area was incomplete. Two weeks after treatment, there were 50 per cent as many flies inside the control area as outside; three weeks after treatment, 60 per cent; and four weeks after treatment, 80 per cent. In another area, 2.6 square miles were treated, presumably with the same dosage. The landing rate here was 1.4 before treatment, 1.3 just after treatment, and 0.4 fourteen hours later. In another area there was complete disappearance of adults after spraying 2.3 square miles, due "partially to natural conditions" and a 50 per cent decrease the next morning.

Since the area used by Brown *et al.* (1950) in his adult control experiments was in the center of a 200 square mile larval control area (Hocking and Richards, 1952), his data probably reflect the results of both treatments.

Wanson (1950), in the Belgian Congo, used 4 per cent BHC and 20 per cent DDT fogs from airplanes to kill resting *Simulium damnosum* adults in wooded areas. Later, larval breeding areas were fogged every other day to kill recently emerged flies and flies preparing for oviposition. Another operation was to fog during periods of especially heavy migration of blackflies from untreated areas. In view of the virtual absence of blackflies in Leopoldville for two years, the fogging operation was considered successful.

Brown (1952) reported on the use of aircraft equipped with a rotary bush spraying apparatus. Spraying runs were made 300 yards apart, at a height of 100 feet and a speed of 150 m.p.h., using DDT in oil solution. The following reductions in adult blackfly populations at different dosages were cited: 24 per cent reduction at 0.11 pound of DDT per acre; 80 per cent reduction at 0.22 pound of DDT per acre, and 87 per cent reduction at 0.27 pound of DDT per acre.

DISCUSSION OF RESULTS OF CONTROL OPERATIONS DIRECTED AGAINST ADULTS

There is general agreement that the freedom from blackflies which occurs after fogging, mist blowing or spraying, is, at best, transitory. It is also agreed that the larger the fogged area, the better will be the control in the center of it, and the longer the control will last.

In spite of the limitations implied by the above observations, there are a number of situations where adult control measures have considerable value. They are useful particularly where there is to be temporary occupancy of a work location or recreation area. The sites of lumber camps, road-building operations and power line and telephone line maintenance and construction work are examples of locations where temporary control of adult blackflies may be accomplished. Temporary control may also be desirable where a summer camp or summer cottage area is the scene of late spring repair work or work to prepare the site for summer occupancy; and in the frequent instances where summer camps are not opened until after the worst of the blackfly season is over, but where there may be occasional rises in blackfly activity, which require suppression.

In most of these situations, the fogging and/or spraying equipment and competent operators should be available locally on short notice on a standby basis. With an expensive, complicated machine like a helicopter, with which the best results have been obtained, this requirement is obviously very difficult to fulfil, except possibly in a military installation or during military operations. This difficulty was an important stimulus to research on and acceptance of larval control by stream treatments.

STREAM TREATMENTS FOR CONTROL OF BLACKFLY LARVAE

I HAND APPLICATION OF LARVICIDES

REVIEW OF LITERATURE

Many early workers believed that blackflies could be controlled by killing the larvae in the streams. Riley (1887) attempted to reduce blackfly larval populations by treating streams with freshly burned lime, emulsions of kerosene, powdered pyrethrum, carbon bisulphide, powdered cocculus indicus and tobacco soap. He reported some larval mortality, but concluded that it was virtually impossible to reduce blackfly larval populations by killing them in streams in the early spring because of the large amounts of toxicants required. He suggested that treatments might be effective when the water is low and that larvae could be controlled by removing all logs, sticks and leaves from the streams.

Weed (1904) reported that blackfly larvae were eliminated from short sections of streams that had been treated with either heavy, non-miscible or light, "soluble" Phinotas oil, and that they could be killed by brushing them from the substrata with stiff brooms. Sanderson (1910) reported that Phinotas oil was an effective larvicide. Reeves (1910) suggested the use of stiff brooms to brush larvae from their attachment points as a control measure.

In 1926, O'Kane reported that the heavy, insoluble Phinotas oil was less effective than the light soluble oil. In an attempt to give a quantitative estimate of the amount of larvicide required for blackfly control, he reported that an amount sufficient to give the water a solid-white appearance for five minutes was effective in eliminating blackfly larvae for short distances.

Rubtzov and Vlasov (1934) appear to have been the first workers to report exact dosages used in larval control experiments. They used 80 different emulsions which were tested by dipping larvae, inclosed in glass tubes with muslin covered ends, for varying periods into larvicide. The tubes were then placed in a stream and the dead larvae counted after 24 hours. In these field tests, xylol was the best larvicide tested, killing all larvae at a dosage of 1 part to 200 parts water when larvae were dipped in for 3 to 3.5 minutes. Kerosene required a concentration of 1 to 100 parts of water when larvae were dipped for three minutes. A sharp drop in toxicity of kerosene was noted at 0 degrees C. and a sharp rise above 15 degrees C. In an experimental stream treatment, kerosene was effective at 1 part to 100 parts of water, but was

quickly "absorbed" by vegetation. It was noted that heavy oils were less effective than light oils. Laboratory tests of nicotine, calcium arsenite, paris green, sodium fluoride, and sodium fluosilicate were also made. Paris green killed all larvae at a concentration of 1 part to 1000 parts of water when they were immersed for five minutes.

In the experiments cited, the use of oils, the earlier insecticides and mechanical control measures were all demonstrated to be effective in reducing blackfly larval populations. However, no large scale control programs were initiated, presumably because of the expense, the difficulties and the injury to stream fauna which occurred or might occur with the methods and materials studied.

In their outstanding pioneer work in Guatemala, Fairchild and Barreda (1945) found that dosages of as little as 0.1 p.p.m. of DDT emulsion applied over a 60-minute period would effectively destroy blackfly larvae for distances of up to 10 kilometers. They experimented with the use of plaster of paris blocks, sponge gourds and sacks of sawdust impregnated with larvicides and then placed in streams to release the insecticide gradually. Since that time, much experimental work has been done using various insecticides and methods of application in an effort to find easy and inexpensive methods of reducing blackfly larval populations.

Garnham and McMahon (1947) experimentally eliminated blackfly larvae from a stream in Kenya by dripping 5 per cent DDT in kerosene and cutting oil into a stream. The calculated dosage was 0.2 p.p.m. for 35 minutes. Because of the success of this experiment, all streams in an area of 65 square miles were treated to eradicate *Simulium neavei*, a vector of onchocerciasis in the area. The nearest breeding site outside of the control area was six miles away across a range of hills and in another watershed. Fifteen per cent DDT emulsifiable concentrate and 20 per cent DDT in toluene and soap, and other DDT formulations were used in these treatments. The larvicide was applied with drip cans. Dosages varied from 1.3 to 34.6 p.p.m. for 30 minutes (with some "token" treatments). The treatments were repeated 10 times at 10-day intervals and then every two weeks and finally every month for an over-all period of five months. Intensive collections were made for six months after the final treatment. No *S. neavei* adults were found inside of the control area during this period.

Prévost (1947) in Canada, reported that streams treated with DDT-impregnated plaster blocks at concentrations of 0.1 to 0.005 p.p.m. for 48 hours were completely freed of larvae.

Hocking *et al.* (1949) in Canada, found that DDT in fuel oil, as a wettable powder suspension, or as an emulsion gave good control with

dosages of 0.1 p.p.m. for 15 minutes when poured, dripped or sprayed into a stream. Gamma BHC gave 50 per cent control when used at the rate of 0.1 p.p.m. for 15 minutes and a high percentage of control at 0.2 p.p.m. for 15 minutes. Fuel oil alone was ineffective at 1.7 p.p.m. for 15 minutes. Chlordane and toxaphene were poor larvicides at the concentrations tested. *Simulium venustum* larvae were in the majority during the testing period.

Gjullin *et al.* (1949a), in Alaska, reported that DDT in acetone suspension caused complete detachment for 150 yards or more when applied at the rate of 0.3 p.p.m. for 15 minutes. DDT in fuel oil was effective when applied at the rate of 0.4 p.p.m. for 15 minutes, DDT in kerosene at 0.3 p.p.m. for 15 minutes, and DDT emulsion at 0.7 p.p.m. for 15 minutes. Application was made with gallon aspirator bottles with a calibrated rate of discharge. Toxaphene and gamma BHC were less effective than DDT. Chlordane was not effective at 0.5 p.p.m. for 15 minutes. Dimethyl phthalate; n-butyl mesityl oxide oxalate; 2-ethyl-1, 3 hexanediol; mono- and dimethylnaphthenes, fuel oil and kerosene were ineffective at the concentrations tested.

Travis (1949), in Alaska, reported that DDT, TDE and methoxychlor were about equally effective as blackfly larvicides. The most practical method of treatment was considered to be DDT in fuel oil applied at the rate of 0.4 p.p.m. The duration of application was not noted. "Parathion was more effective than other materials but not sufficiently superior to warrant its use in streams where fish are present." BHC, chlordane and toxaphene were found to be inferior to DDT as blackfly larvicides.

Kindler and Regan (1949), in New Hampshire, treated 200-foot stream sections experimentally with larvicides. They found that DDT emulsion at 0.05 p.p.m., TDE emulsion at 0.2 p.p.m., and 12 per cent gamma BHC at 0.2 p.p.m., all applied over a 10-minute period, were good larvicides. Pyrethrins, chlordane and acetone alone were very poor larvicides. Blackfly larvae were nearly eliminated from five miles of a stream treated at mile intervals with 0.2 p.p.m of TDE emulsion for 10 minutes. Larvae in these experiments were *Prosimulium hirtipes* and *Simulium venustum*.

Hocking (1950), in Canada, reported that 15 per cent parathion wettable powder at 0.2 p.p.m. for 15 minutes gave good control but gave no control at 0.033 p.p.m. for 15 minutes. Ten per cent DDT in fuel oil gave good control at 0.1 and 0.07 p.p.m. for 15 minutes. Dieldrin at 0.2 p.p.m. for 15 minutes gave excellent results against *Prosimulium hirtipes*. When used as a wettable powder poor results were reported. Aldrin was a poor larvicide when used as an emulsifiable concentrate,

wettable powder, or in fuel oil. Methoxychlor used as a powder gave good control. Trichlorobenzene gave poor control. Gamma BHC was poor when used as an emulsion but gave good control when used as a wettable powder at the rate of 0.2 p.p.m. for 15 minutes or in fuel oil at the rate of 0.1 p.p.m. for 15 minutes. The larvicide was introduced into the stream by a variety of methods in these tests. It was dropped in with a medicine dropper, poured in with a graduate or dribbled in with a special dispenser. Species in these tests were *Simulium arcticum*, *S. tuberosum*, *S. latipes*, *Prosimulium hirtipes*, *P. onychodactylum*, *P. decemarticulatum*, an unidentified species of *Prosimulium*, and two unidentified species of *Cnephia*.

Quoting an unpublished report of Twinn, Hocking reported that 5 per cent DDT in kerosene applied at the rate of 0.14 p.p.m. for 10 minutes gave good control in a large river for 20 miles below the treatment point. Many larvae were present at the time of treatment, and pupae of *S. arcticum*, *S. venustum*, and probably *S. pugetense* and *S. decorum* were collected.

Wanson (1950) reported that stream treatment with dosages of 3 mg. per kilogram of water per minute with BHC wettable powder controlled *S. damnosum* larvae. However, under Belgian Congo conditions, that is, nearly continuous breeding, larval control measures proved to be uneconomical. In this case, adult blackfly control measures proved to be more satisfactory (see p. 23).

Hocking and Richards (1952) reported that 42 streams in Labrador were treated by hand from the ground and seven from boats. The desired dosage in these treatments was 0.1 p.p.m. DDT in fuel oil and auxiliary solvent applied over a 15-minute period. The insecticide was dribbled directly into the streams in most cases. Two streams were treated using DDT-soaked sand in muslin bags. No larvae were found in the treated streams checked after treatment. Nineteen described and six undescribed species of blackflies were collected in the treated area.

Although the papers cited do not agree on the relative toxicity of the different larvicides, the best formulation, the best method of application or the minimal dosages, there is general agreement that DDT was the most acceptable larvicide among those tested, and on the approximate dosage of this insecticide required for control. It was shown that DDT could be used in oil solution or as an emulsion or emulsifiable concentrate at dosages between 0.1 and 0.4 p.p.m. for 15 minutes when applied by aircraft or by hand spraying or pouring. When DDT-impregnated plaster of paris blocks were used, a dosage of 0.005 p.p.m. or less for 48 hours was effective.

Limited field tests of chlordane, toxaphene, dimethyl phthalate, n-

butyl-mesityl oxide oxalate, 2-ethyl-1, 3 hexanediol, mono- and dimethylnaphthenes, aldrin, trichlorobenzene, pyrethrins, acetone, fuel oil, kerosene, nicotine, calcium arsenite, paris green, sodium fluoride, and sodium fluosilicate indicate that these chemicals, as applied, were less promising than DDT, lindane, TDE, dieldrin and parathion.

EXPERIMENTS IN THE ADIRONDACKS

It was evident, both from the conflicting results reported in the literature and from our experiments in the Adirondacks, that there are important factors in addition to the kind and amount of insecticide applied and the method of application that must be considered when streams are treated for blackfly control. Large streams and rivers apparently require proportionately less insecticide than smaller streams. The effective distance in larger streams is greater than in smaller ones. This may be because larger streams usually have proportionately less area of contact with the stream bed and fewer pools or beaver dams to impede flow. Some of the larger streams may approach the condition of the smaller streams as the summer progresses, making treatment later in the season more difficult.

Another factor of importance in control may be the age of the larvae. There is some evidence, both in the Adirondack work and in the literature (Gjullin *et al.*, 1950; Rubzov and Vlasov, 1934; and Kindler and Regan, 1949) that younger larvae are easier to kill than older larvae. There appeared to be no differences in susceptibility of the different species found in the Adirondacks.

Finally, there is the possibility of error in evaluating treatments due to the frequently sudden seasonal changes in larval populations. In the early spring this is sometimes particularly noticeable when *Prosimulium hirtipes* and *Cnephia mutata* pupate and emerge. It is essential to know the species involved and their biologies.

The dosage of larvicide for hand application experiments was calculated as follows: the width and depth of the stream were measured a short distance below the treatment point where the flow was relatively smooth and the sides and bottom regular. The rate of flow at this point was calculated after determining the time required for a cork to be carried 10 feet. The average figure for three trials was used and the average rate of flow was considered to be two-thirds of the surface rate (Hocking *et al.*, 1949). The number of ounces of water which flowed by the treatment point during the period of application was then compared to the number of ounces of larvicide applied during that period. The figures thus derived were expressed in terms of parts of insecticide per million parts of water (p.p.m.).

Data on larval control obtained from experimental hand application of insecticides to Adirondack streams in 1950, 1951 and 1952 are summarized in tables 1a and 1b. Descriptions of the streams are given in the pages following the tables. The apparent inconsistencies in the effectiveness of some of the treatments are discussed in the following section. Most of the streams are shown, without identifying them, on the map (fig. 3). The two principal methods of hand application that were used were the placing in the streams of insecticide-impregnated plaster of paris blocks (fig. 4), and spraying or pouring of a solution or emulsion of the insecticide into the stream. Details of these methods are given in the Appendix.

Characteristics of Streams Studied in Experiments

In order better to understand the outcome of a given test, and to use it as a basis for further work, reference to peculiarities of the stream involved is necessary. In the following paragraphs, the streams mentioned in table 1 are listed, with their general location and length; typical width, depth and rate of flow in late spring of the sections studied; the character of the bottom, general remarks on other points, and the species of blackfly larvae found in each stream. The streams are listed in the order in which they appear in table 1a.

1 Wheeler Creek: flows west and north into Seventh Lake; 4 miles long, 11 feet wide, $1\frac{1}{4}$ feet deep, flow $2\frac{1}{2}$ f.p.s.; bottom of sand, gravel and stones; flow and volume decrease greatly during summer; flows through deep woods with occasional large grassy clearings with grass trailing in the water. Blackfly larvae: *Prosimulium hirtipes*, *Cnephia mutata*, *Simulium venustum*, *S. tuberosum*, *S. gouldingi* and *S. aureum*.

2 High Rock Pond Outlet: flows west into Seventh Lake at east end; 4 miles long, 17 feet wide, 9 inches deep, flow $2\frac{1}{2}$ f.p.s.; flow and volume decrease greatly during summer; bottom of fine sand and mud at lower end, coarse sand and stones toward source; aquatic vegetation sparse, some green algae on rocks in summer; flows through deep woods, with lower end swampy. Blackfly larvae: *Prosimulium hirtipes*, *Cnephia mutata*, *Simulium venustum*, *S. tuberosum*, *S. gouldingi* and *S. parnassum*.

3 Gulf Creek: flows southwest into Kayuta Lake near Forestport; 3 miles long, $2\frac{1}{2}$ feet wide, 9 inches deep; flow 2 f.p.s.; bottom rocky with coarse sand base; flows through open woods, gradual slope; three dams and ponds obstruct its flow. Blackfly larvae: *Prosimulium hirtipes*, *Cnephia mutata*, *Simulium venustum*, *S. vittatum*, *S. decorum* and *S. tuberosum*.



Figure 4. Placing DDT-impregnated plaster block in a stream.

TABLE 1a
Dosages of DDT in Streams Treated as Indicated

Dosage in p.p.m.	Duration of treatment	Distance controlled	Duration of effect	Species controlled	Stream	Treatment date
<i>A Treatment with DDT-impregnated plaster of paris blocks</i>						
0.0005	24 hrs	1.0 mile*	52 days	<i>hirtipes, mutata</i>	Wheeler Creek	5/7/50
0.001	24 hrs	1.25 miles*	48 days	<i>hirtipes, mutata</i>	High Rock Pond Outlet	5/11/50
0.002	24 hrs	0.75 mile*	73 days	<i>hirtipes, mutata</i>	Gulf Creek	4/4/52
0.003	24 hrs	0.5 mile	2 yrs	<i>hirtipes, mutata, venustum</i>	Aedes Brook	5/27/50
0.003	24 hrs	0.5 mile*	6 mos	<i>hirtipes</i>	Nursip Brook	5/27/50
0.003	48 hrs	0.0 mile	0	<i>hirtipes</i>	Gull Lake Outlet	11/23/51
0.003	48 hrs	1.0 mile*	2 yrs	<i>hirtipes, mutata</i>	Townsend Pond Outlet	4/28/50
0.008	24 hrs	0.33 mile*	67 days	<i>tuberosum, gouldingi</i>	Kincaid Road Stream	5/22/52
0.01	48 hrs	0.33 mile*	2 yrs	<i>hirtipes, mutata</i>	Townsend Pond Inlet	4/29/50
<i>B Treatment with emulsifiable DDT sprayed or poured into stream</i>						
0.094	20 min	0.5 mile*	54 days	<i>venustum, tuberosum</i>	Lower Rd Meadow Str.	5/19/52
0.1	20 min	400 yds*	11 days	<i>venustum</i>	Trib. Pine Creek	5/8/52
0.228	20 min	1.75 miles*	56 days	<i>hirtipes, mutata, loisae</i>	Pine Creek	3/21/52
0.287	20 min	1.0 mile*	37 days	<i>hirtipes, mutata</i>	Cascade Brook	3/14/52
0.314	20 min	2.0 miles*	78 days	<i>hirtipes, mutata, vittatum</i>	2d Okara Outlet	3/26/52
<i>C Treatment with DDT in oil solution sprayed or poured into stream</i>						
0.023	20 min	0.5 mile*	13 days	<i>venustum, tuberosum</i>	Salmon River	8/15/51
0.1	20 min	0.0 mile*	0	<i>hirtipes, mutata, vittatum</i>	2d Okara Outlet	11/23/51
0.242	20 min	0.25 mile*	126 days	<i>hirtipes</i>	Gull Lake Outlet	4/4/52
1.13	20 min	0.2 mile	—	<i>venustum, tuberosum, gouldingi</i>	Wheeler Creek	6/18/52
1.4	20 min	0.5 mile	—	<i>venustum, tuberosum, aureum, parnassum</i>	Aedes Brook	6/24/52
<i>D Treatment with 50% DDT dust (in talc) sifted slowly into stream</i>						
0.16	20 min	0.5 mile*	21 days	<i>venustum, tuberosum</i>	Salmon River	8/4/42

* Last checked distance.

TABLE 1b
Dosages of Insecticides Other than DDT in Streams Treated as Indicated

Dosage in p.p.m.	Duration of treatment	Distance controlled	Duration of effect	Species controlled	Stream	Treatment date
<i>A Treatment with TDE-impregnated plaster of paris blocks</i>						
0.003	48 hrs	0.13 mile	40 days	<i>hirtipes</i> , <i>venustum</i>	High Rock Pond Outlet	5/24/51
0.008	48 hrs	0.5 mile	42 days	<i>venustum</i> , <i>tuberosum</i> , <i>gouldingi</i>	Wheeler Creek	6/7/51
<i>B Treatment with emulsifiable TDE sprayed or poured slowly into stream</i>						
0.012	20 min	0.5 mile*	6 days	<i>venustum</i> , <i>tuberosum</i> , <i>hirtipes</i>	Cascade Brook	6/3/52
0.206	20 min	1.75 miles*	16 days	<i>venustum</i> , <i>tuberosum</i>	Pine Creek	8/4/52
0.345	20 min	0.75 mile*	34 days	<i>venustum</i> , <i>tuberosum</i>	Bear Brook	7/22/52
<i>C Treatment with lindane-impregnated plaster of paris blocks</i>						
0.0004	24 hrs	0.0 mile	0 days	<i>hirtipes</i> , <i>mutata</i> , <i>vittatum</i>	Gulf Creek	3/21/52
<i>D Treatment with emulsifiable lindane sprayed or poured slowly into stream</i>						
0.1	20 min	0.5 mile*	14 days	<i>venustum</i> , <i>tuberosum</i>	Salmon River	7/17/52
0.35	20 min	0.0 mile	0 days	<i>venustum</i> , <i>tuberosum</i> , <i>gouldingi</i> , <i>hirtipes</i>	Wheeler Creek	6/5/52
0.034	20 min	0.0 mile	0 days	<i>venustum</i>	Indian Brook	5/27/52
0.068	20 min	0.25 mile	—	<i>venustum</i>	Indian Brook	5/29/52
1.88	20 min	0.2 mile*	—	<i>venustum</i>	Trib. Split Rock Cr.	6/13/52
<i>E Treatment with emulsifiable dieldrin poured into stream</i>						
1.85	20 min	1.0 mile*		<i>venustum</i> , <i>tuberosum</i> , <i>hirtipes</i>	High Rock Pond Outlet	6/18/52

* Last checked distance.

4 Aedes Brook: flows north under Moose River fire trail about $3\frac{1}{2}$ miles southeast of Big Otter Lake; 1 mile long, 2 feet wide, 2 inches deep; flow $1\frac{1}{3}$ f.p.s.; bottom coarse sand and small stones with scattered larger stones; aquatic vegetation scanty; flows through dry woods down a steep hill above the fire trail; numerous small pools with dead leaves and other organic debris, with some underground flow. Blackfly larvae: *Prosimulium hirtipes*, *Cnephia mutata*, *Simulium venustum*, *S. tuberosum*, *S. gouldingi*, *S. aureum* and *S. parnassum*.

5 Nursip Brook: flows north into Seventh Lake; $\frac{1}{2}$ mile long, 4 feet wide, 6 inches deep; flow $2\frac{1}{2}$ f.p.s.; bottom generally sandy and rocky, but pools have muddy bottoms; makes a steep descent through open woods, very low in summer; narrower and deeper on the average than dimensions given. Blackfly larvae: *Prosimulium hirtipes*, *Cnephia mutata*, *Simulium tuberosum*, *S. aureum* and *S. gouldingi*.

6 Gull Lake Outlet: flows southwest into Moose River between McKeever and Thendara; 1 mile long, 5 feet wide, 5 inches deep; flow $2\frac{1}{2}$ f.p.s.; bottom of upper portion with large boulders, lower part with stretches of sand bottom with some vegetation; some underground flow. Blackfly larvae: *Prosimulium hirtipes* and *Simulium tuberosum*.

7 Townsend Pond Outlet: flows west into Big Moose Lake Outlet (north branch of Moose River); 1 mile long, 4 feet wide, 6 inches deep, flow $1\frac{1}{2}$ f.p.s.; bottom of sand, pebbles and rocks; moderate descent through open woods; volume declines sharply in midsummer but does not dry up. Blackfly larvae: *Prosimulium hirtipes*, *Cnephia mutata* and *Simulium tuberosum*.

8 Kincaid Road Stream: flows west into Little Woodhull Creek near Forestport; $\frac{1}{4}$ mile long, 1 foot wide, 3 inches deep, flow $2\frac{1}{2}$ f.p.s.; bottom of coarse sand and pebbles alternating with mud; originates from a spring, descends gradually through woods. Blackfly larvae present: *Simulium tuberosum* and *S. gouldingi*.

9 Townsend Pond Inlet: flows southwest into Townsend Pond; $\frac{1}{3}$ mile long, 2 feet wide, 6 inches deep, flow $1\frac{1}{4}$ f.p.s.; bottom, of rocks and dead leaves over coarse sand; upper portion pools and falls, lower portion deeper with grassy banks. A temporary stream. Blackfly larvae: *Prosimulium hirtipes* and *Cnephia mutata*.

10 Lower Meadow Stream: flows west into Kayuta Lake near Forestport; $\frac{1}{2}$ mile long, 1 foot wide, 8 inches deep, flow, 2 f.p.s.; bottom of fine sand with considerable vegetation; uninterrupted flow from dam to lake. Blackfly larvae present: *Cnephia mutata*, *Simulium venustum*, *S. tuberosum*, *S. vittatum* and *S. aureum*.

11 Upper Road Tributary of Pine Creek: flows south into Pine Creek near Forestport; 1 mile long, 3 feet wide, 6 inches deep,

flow $1\frac{8}{10}$ f.p.s.; bottom of fine sand and mud, with twigs and leaves; flows through meadow. Blackfly larvae: *Prosimulium hirtipes*, *Cnephia mutata*, *Simulium venustum*, *S. croxtoni*, *S. aureum* and *S. latipes*.

12 Pine Creek: flows southwest into Kayuta Lake near Forestport; 5 miles long, 6 feet wide, $1\frac{1}{4}$ feet deep, flow $2\frac{1}{2}$ f.p.s.; bottom of coarse and fine sand; few riffles, but mostly a deep water, sand bottom stream, swampy toward lower end. Blackfly larvae: *Prosimulium hirtipes*, *Cnephia mutata*, *C. loisae*, *Simulium venustum* and *S. tuberosum*.

13 Cascade Brook: flows west from Cascade Lake into Moss Lake, between Eagle Bay and Big Moose; 2 miles long, 9 feet wide, 8 inches deep, flow $1\frac{1}{10}$ f.p.s.; bottom of fine sand and mud at upper end, coarse sand and rocks toward lower end; grassy bank with trailing grass, upper portion with beaver dams and ponds, lower portion relatively unobstructed except deeper and slower toward lake. Blackfly larvae: *Prosimulium hirtipes*, *Cnephia mutata*, *Simulium vittatum*, *S. venustum*, *S. tuberosum*, and *S. decorum*.

14 Second Okara Outlet: flows south from Okara Lake into Moose River near Thendara; 2 miles long, 8 feet wide, 5 inches deep, flow 2 f.p.s.; bottom of fine and coarse sand with areas of small and large rocks, several beaver dams, with ponds in which bottom is muddy. Flows mostly through alder thickets and low grassy meadows. Blackfly larvae: *Prosimulium hirtipes*, *Cnephia mutata*, *Simulium venustum*, *S. tuberosum*, *S. decorum* and *S. vittatum*.

15 Salmon River: flows from Salmon Pond into South Pond, between Blue Mountain Lake and Long Lake; 3 miles long, 20 feet wide, 6 inches deep, flow $1\frac{3}{4}$ f.p.s.; bottom, coarse with stones and boulders; little vegetation; pools near lower end. Blackfly larvae: *Prosimulium hirtipes*, *Simulium venustum*, *S. tuberosum* and *S. aureum*.

16 Bear Brook: flows north through swamp into Marion River at Utowana Lake; 3 miles long, 6 feet wide, 9 inches deep, flow 2 f.p.s.; bottom of coarse sand and pebbles with boulders and stones; very little vegetation, flows through swamp near source, but swift and rocky toward mouth. Blackfly larvae: *Prosimulium hirtipes*, *Cnephia mutata*, *Simulium venustum*, *S. tuberosum* and *S. parnassum*.

17 Indian Brook: flows northeast into Moose River at Indian Rapids; 3 miles long, 7 feet wide, $1\frac{1}{2}$ feet deep, flow $1\frac{1}{2}$ f.p.s.; bottom mostly fine sand with sections of coarse sand pebbles, and stones; flows through open country with alder thickets; has gradual slope, many beaver dams and ponds. Blackfly larvae: *Prosimulium hirtipes*, *Cnephia*

mutata, *C. dacotense*, *Simulium venustum*, *S. tuberosum*, *S. decorum*, *S. aureum* and *S. vittatum*.

18 Tributary of Split Rock Creek: flows south into Split Rock Creek between McKeever and Thendara; 1 mile long, 16 inches wide, 4 inches deep, flow $\frac{2}{10}$ f.p.s.; bottom of fine sand with grass and other vegetation; a small stream in light woods; semipermanent. Black-fly larvae: *Prosimulium hirtipes*, *Cnephia mutata*, *Simulium venustum* and *S. aureum*.

Miscellaneous Notes on Treatments of Different Streams (See also tables 1a and 1b)

1 Wheeler Creek: Treatments in 1951 and 1952 produced comparatively poor results, due probably to the fact that the treatments were made late in the season when the stream was relatively low. As a stream becomes lower, the amount of contact of water with stream bed becomes proportionately greater and the chances for adsorption of the insecticide on mud, sand and vegetation increased. In addition, obstacles to flow, such as pools, beaver dams and areas of still water, have a relatively greater obstructive effect.

2 High Rock Pond Outlet: Conditions similar to those in Wheeler Creek resulted in similarly poor control with a late treatment of TDE. Later, a heavy dose of dieldrin (1.85 p.p.m. for 20 minutes) eliminated larvae from the stream even though the water was low at the time of treatment.

13 Cascade Brook: had very little interruption to flow in the treated portion. Its volume and flow remained high during the summer. Because of these characteristics lower dosages gave good control.

15 Salmon River: The largest of the "typical" experimental streams, with relatively little interruption to flow or decline in volume, so that comparatively low dosages were effective.

16 Bear Brook: Probably a smaller dosage would have been effective.

4 Aedes Brook: One of the smallest streams studied; difficult to control larvae in this stream because of the numerous small pools, underground flow etc. Has a large number of species of blackflies.

9 Townsend Pond Inlet: By late spring this stream becomes discontinuous. The effects of the heavy treatment in 1950 were evident in 1951 and 1952, since larvae were present above but not below the 1950 treatment point.

7 Townsend Pond Outlet: Treated with heavy dosage in April 1950; larvae not found again below the treatment point until July 18, 1952, when *S. tuberosum* larvae were found.

12 **Pine Creek:** Control was obtained even though the stream was obstructed by three large successive beaver dams with at least a quarter of a mile of slow water.

Summary and Discussion of Information on Hand Application of Larvicides

From the data in table 1a it was concluded that DDT-impregnated plaster of paris blocks effectively reduced blackfly larval populations for distances of at least 1.25 miles in large, relatively unobstructed streams when dosages of 0.0005-0.001 p.p.m. for 24 hours were applied. Smaller streams with relatively unobstructed flow were cleared of blackflies for distances of up to one-half mile by dosages of 0.003 p.p.m. for 24 hours to 0.003 p.p.m. for 48 hours. Much heavier dosages were required for control in smaller, obstructed streams. The maximum distance that control would be effective in small streams was difficult to ascertain since most of these streams were relatively short, but available data indicate that the distance is much shorter than in larger and longer streams which were less likely to have an impeded flow.

DDT in solution or emulsifiable concentrate was effective in unobstructed streams at concentrations of 0.094 to 0.314 p.p.m. for 20 minutes, but was not effective, even with much higher dosages (up to 1.4 p.p.m. for 20 minutes) in obstructed streams.

TDE and lindane in plaster of paris blocks, solution and emulsion were effective in about the same dosages as DDT.

Dieldrin was tested only once in an emulsion. The stream flow was moderately obstructed at the time of treatment but a dosage of 1.88 p.p.m. for 20 minutes cleared larvae from the stream.

II APPLICATION OF LARVICIDE BY AIRCRAFT

Aircraft application of insecticides to control blackfly larvae has certain distinct advantages over hand application: more complete coverage of streams is obtained, especially in the less accessible areas; there is less danger of overdosing streams; the operation can be completed more quickly at the proper time and can be more closely supervised.

REVIEW OF LITERATURE

In 1947, Hocking *et al.*, although primarily interested in mosquito control, reported on the effects of airplane treatments on blackfly larvae. A C-47 plane was used to apply a 5 per cent DDT solution in fuel oil at a mean concentration of 0.26 pound per acre over half-mile lengths of stream. Later a dosage of 0.48 pound per acre was applied over one of these streams above the area treated in the first experiment. Large

numbers of larvae (mostly *Simulium venustum*) but no pupae were present before treatment. Neither larvae nor pupae were found a few days after treatment.

Travis (1949) reported that DDT in fuel oil and auxiliary solvent, when applied at the rate of 0.1 pound per acre, caused complete larval detachment for one-half mile downstream when one 100-foot swath was flown across a stream. When 400 to 2400-foot swaths were flown there was larval detachment for 1 to 2.5 miles downstream.

In 1948, Gjullin *et al.* (1949b) used a C-47 and an L-5 to treat streams from the air. A 20 per cent DDT solution containing fuel oil and auxiliary solvent was used. The C-47 laid down swaths about 800 feet in width at the rate of 0.1 pound DDT per acre. Under these conditions, a single swath flown directly across a stream resulted in complete disappearance of larvae for an average distance of over two miles downstream. Two successive swaths were flown over each of two streams, but there the effects extended no farther than when one swath was applied. In one case, three successive swaths were flown over a river with 100 per cent detachment downstream for only one mile.

The L-5 was calibrated to deliver 0.2 pound of DDT in 20 per cent solution with a swath width of 100 feet. When one swath was flown across a stream there was 100 per cent detachment for two miles below. In these experiments, if more than one swath was applied, each covered the same section of stream. It was noted that the larvicide was over 90 per cent effective for a long distance below the point where it ceased being 100 per cent effective. The 800-foot swath width at 0.1 pound per acre was 92 per cent effective 3.5 miles, 81 per cent at 4 miles, 70 per cent at 5 miles, and 58 per cent effective at 7.5 miles below the treatment point. Species present at the time of treatment included *Prosimulium onychodactylum*, *Simulium arcticum*, *S. vittatum*, *S. corbis*, and the *S. venustum*-*S. tuberosum* (as *S. vandalicum*) complex. There were no discernible species differences in susceptibility to the larvicide.

Gjullin *et al.* (1950) attempted to eliminate overwintering larvae from Alaskan streams with 20 per cent DDT in fuel oil and auxiliary solvent applied by aircraft. Treatment of Little Solomon Creek on May 5th, at the rate of 0.1 pound per acre, based on a swath width of 800 feet, caused no reduction in larval populations in 24 hours. The stream was sprayed again with an additional swath, with no reduction noted 300 feet downstream. In sharp contrast, after similar applications during the summer of 1948, complete detachment of larvae below the treatment points for 1.5—2.5 miles was recorded.

On May 7th, Naknek River and tributaries, for 30 miles upstream, were treated at intervals of about one mile. Twenty-four hours later, all small larvae were detached but there was no apparent reduction in numbers of large larvae. On June 25th, the streams were resprayed; larval populations were high before treatment. Spraying was done in a 12 to 24 m.p.h. wind. Nearly complete elimination of larvae from these streams was reported.

Arnason *et al.* (1949) used a 12 per cent DDT solution dissolved in 1 part Velsicol AR-50 and 9 parts fuel oil with 0.5 per cent Triton X-100 emulsifier and 0.5 per cent Williams Red Dye added. The South Saskatchewan River was treated with 0.13 p.p.m. for 36 minutes. Larvae of *S. arcticum* were almost completely eliminated from the river for a checked distance of 17 miles below the treatment point and there were some indications that the treatment was effective for 90 miles. The North Saskatchewan River was treated at the rate of 0.07 p.p.m. for 34 minutes. Blackfly larvae were apparently unharmed by this treatment. Both of these rivers are large and deep with volume of 35,200 and 63,900 c.f.s. respectively. The amount of DDT used in these two rivers was 1160 pounds.

Twinn (1950) reported that an experimental treatment of the Saskatchewan River with DDT at the rate of 0.1 p.p.m. for 15 minutes practically eliminated larvae for 117 miles.

Goulding and Deonier (1950) checked streams for blackfly larvae before and after application of 12 per cent DDT in kerosene and xylene applied at the rate of 1 pound DDT per acre by aircraft. Blackfly larvae were reported eliminated from all except one of 35 stations on 16 streams. In the one exception, larvae were found 60 days after treatment. It was noted that larvae were dislodged for a distance of three-quarters of a mile beyond the area actually treated in one stream which had one-quarter of a mile of its length inside the control area.

Hocking and Richards (1952) supervised the treatment of 27 streams with 10 per cent DDT solution in fuel oil and auxiliary solvent applied by helicopter. The larvicide was dispersed through a 30-foot rubber hose one-half inch in diameter with a 6-foot length of pipe at the lower end hanging from the helicopter. The calculated dosage in all treatments was approximately 0.1 p.p.m. for 15 minutes. The area was not checked completely after treatment but no larvae were found in the streams that were examined. As part of the same control program, the Hamilton River was treated, using a C-47. The plane flew 30 feet above the river, crossing it obliquely at half-mile intervals. A 15.4 per cent DDT solution was applied at a dosage of 0.1 p.p.m. for 15 minutes, using 403 pounds of DDT. The river had a flow of 72,000 c.f.s. No larvae were found below the treatment point after treatment.

AIRCRAFT SPRAYING IN THE TOWN OF WEBB

In New York State, the first application of larvicide from the air was made from a helicopter in the spring of 1950, in the Town of Webb. A plot approximately 12 miles in length and $2\frac{3}{4}$ miles wide was treated experimentally. The plot was in a relatively inaccessible area northwest of the population centers at the southwestern end of the Fulton Chain of lakes (see map, *fig. 5*). Good larval control was obtained with 0.1 pound DDT per swath acre with a distance of one-quarter mile between swath centers. Details of this treatment are given in a paper by Travis *et al.* (1951).

To state the dosages, the expression "per swath acre" is used instead of dosage *per acre*, because the latter term is misleading when applied to treatments in which the swaths do not overlap or touch. Since there are 43,560 square feet in an acre, a segment of swath 435.6 feet long and 100 feet wide would be 1 swath acre. The amount of insecticide in the strip covered by a swath would be considerably higher than the amounts falling accidentally in the much wider intervals between the swaths. Swaths were flown parallel to the long axis of the plot in such a way as to cross most of the streams at right angles.

In 1951, approximately 90 square miles (an increase of about 2.7 times the area treated in 1950) were treated by airplanes (see map, *fig. 6*). A dosage of 0.017 pound per swath acre gave some control and a dosage of 0.1 pound per swath acre gave good control. Details of this treatment are given in a paper by Collins *et al.* (1952).

In 1952, the area treated from the air was nearly double that treated in 1951, a total of about 175 square miles (see map, *fig. 7*). Spraying was started on April 16th, about two weeks earlier than in 1951 to avoid losses in effectiveness due to pupation of *Prosimulium hirtipes* larvae. The equipment used in 1951 was used again in 1952, except that a single coarse nozzle was used to replace the two fine nozzles on each plane for part of the spraying. This change was made because of the slight to moderate winds which prevailed during the spraying period. Spraying was completed April 19th. A total of 1440 pounds of technical DDT was used, in a mixture of 400 gallons of Sovacide and 400 gallons of fuel oil, making a concentration of approximately 20 per cent DDT. The solution was applied at the rate of 1.33 gallons per linear mile or 0.11 pound of DDT per swath acre.

Since the spray planes were flying at an altitude of about 150 feet, an Aeronca without spray equipment, flying at an altitude of about 2000 feet, was used to guide the spray planes. From 2000 feet the pilot of the guide plane was able to pick out landmarks which were not visible from the spray plane, making possible a more efficient spray operation.

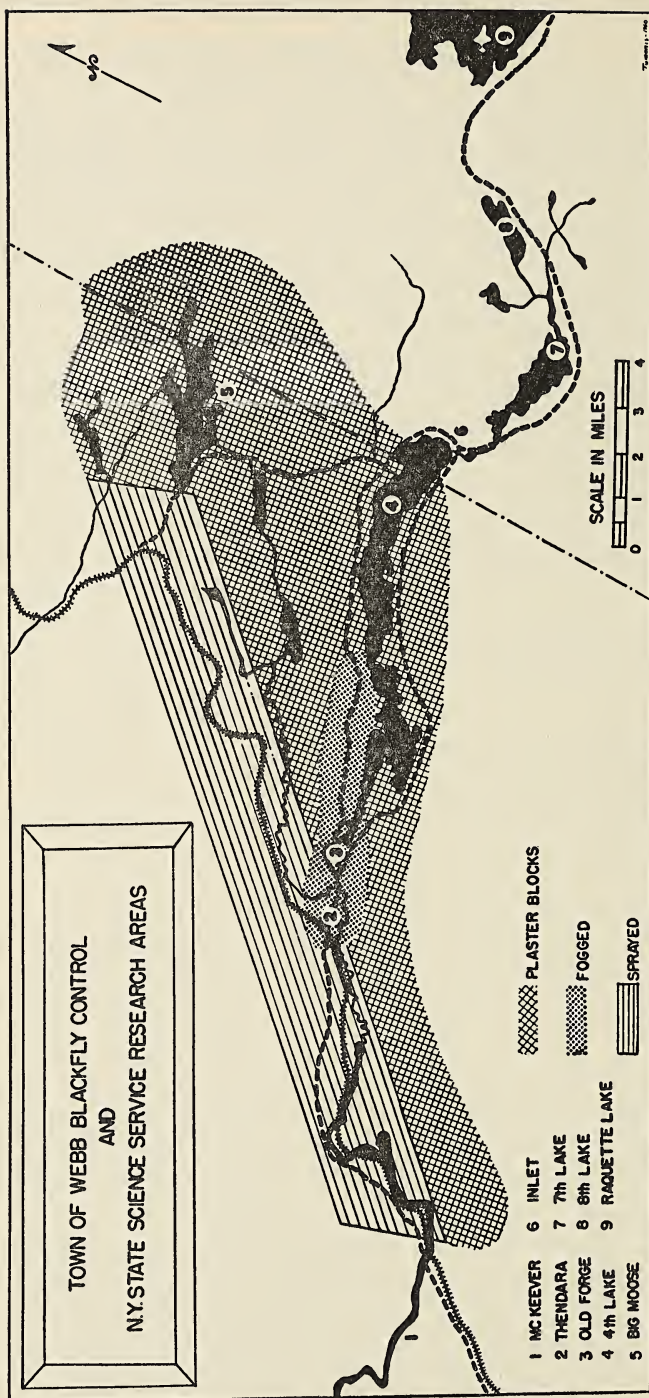


Figure 5. Map of Town of Webb blackfly control areas in 1950, showing three different methods used.

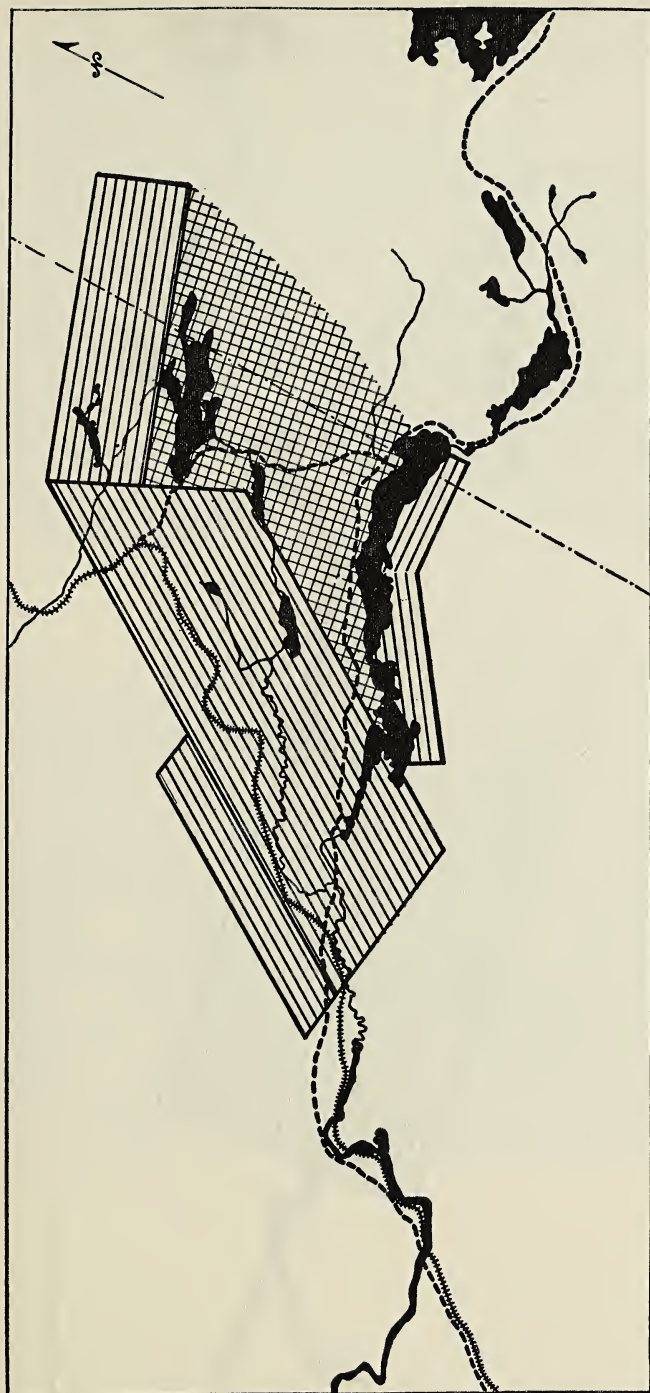


Figure 6. Map of Town of Webb blackfly control areas in 1951.

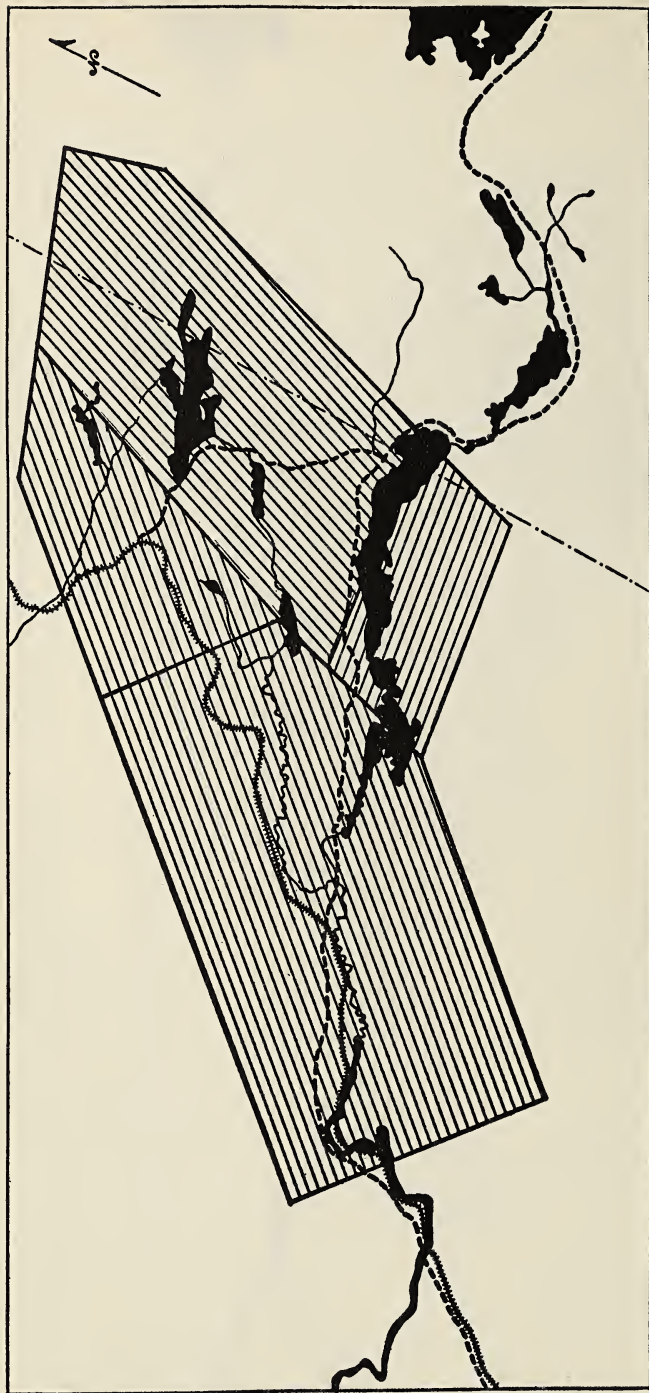


Figure 7. Map of Town of Webb blackfly control areas in 1952.

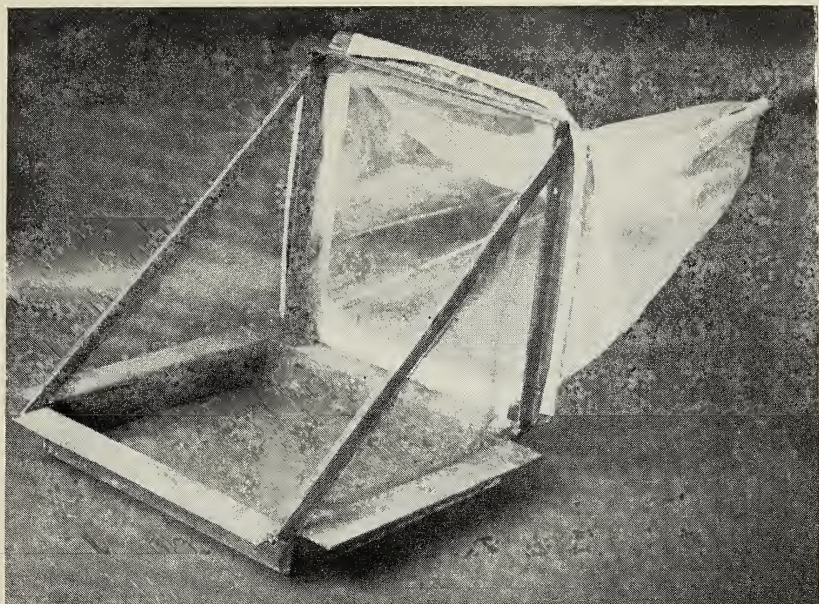


Figure 8. Square foot sampler used in stream studies in the Adirondacks.



Figure 9. Taking a "five-minute sample" using the square foot sampler.

After the pattern spraying was completed, supplementary spray flights were made over streams in "bad" blackfly producing areas between Indian Brook and Middle Settlement Creek, along the south shore of the Fulton Chain, and in areas along the north and south shores of Big Moose Lake.

Results

Nineteen streams in the control area were checked before and after treatment. There was an average reduction of 84 per cent (see table 2). Fifteen streams were virtually cleared of larvae. There was a 99 per cent reduction in one stream and no control in three other streams. Two of the streams which showed no control are short and narrow, the third is longer and about six feet wide. Of nine other streams not checked before treatment, seven had no larvae and two had few to moderate numbers of larvae.

Observers stationed at Indian Brook took five-minute samples (see table 3), before, during and after treatment. A "five-minute sample" was taken by setting the square-foot sampler (figs. 8, 9) in a stream for five minutes and collecting the organisms that were carried into it by the current. Normally, only a few blackfly larvae are collected in a five-minute sample, the number varying with the number of larvae in the stream. In Indian Brook the number of larvae per sample under normal conditions was about 20. This number increased to about 1600 one hour after treatment; one and one-half hours after treatment the number had increased to 3200; the number decreased somewhat but remained high for at least three hours (last sample taken that day). Two days later a five-minute sample indicated that few larvae were being carried downstream (see table 3).

In the three and one-half hours after treatment an average of about 1700 larvae passed through a representative vertical square foot, near the middle of the stream, each five minutes, making a theoretical total of approximately 119,000 larvae in three and one-half hours. The ultimate fate of these larvae is of interest. It was observed that many of them were carried by the current into backwaters or pools. All the larvae examined one day after treatment were alive and active. Two days after treatment some were still alive but many were dead. Five days after treatment all the blackfly larvae were dead and mold was seen growing on the masses of dead larvae.

AIRPLANE SPRAYING IN TOWN OF FORESTPORT

In addition to the spray program in the Town of Webb, about 75 square miles in the Forestport area, including population centers in

TABLE 2

Numbers of Blackfly Larvae in Streams in Treated Areas before and after
Airplane Spraying in 1952 in Town of Webb

<i>Stream</i>	<i>Number of larvae per 10 attachment units*</i>	
	<i>Before treat- ment</i>	<i>After treat- ment</i>
Pancake Brook	50	0
Pancake Junior Brook	40	40
3d stream on Fire Trail	70	0
1st stream before Indian Brook	200	0
Indian Brook proper	5000	50
North Branch Indian Brook	200	0
Bald Mountain Pond Outlet	50	50
OF No. 144 stream, Big Moose	50	rare
Big Moose Outlet	400	0
Townsend Pond Inlet	80	0
Townsend Pond Outlet	1000	0
OF No. 38 stream, South Shore	10	rare
OF No. 31 stream, South Shore	150	rare
OF No. 3 stream, South Shore	400	0
Indian Brook, South Shore	200	0
Cascade Brook	500	rare
2d Little Safford Inlet	20	0
Split Rock Creek	300	300
3d Lake Creek	20	0
West Pond Outlet	—	60
Russian Lake Outlet	—	0
Gull Lake Outlet	—	0
Merriam Lake Outlet	—	0
North Bay Stream	—	0
Andes Creek	—	0
Sisters Outlet	—	0
Haymarsh Outlet	—	20
Last Good Stream	—	0

* An "attachment unit" was a stone, stick or piece of grass, depending on the type of stream.

TABLE 3

Numbers of Dislodged Blackfly Larvae in Five-minute Samples Taken in
Indian Brook at Stated Intervals after Treatment (1952)

<i>Time</i>	<i>No. of blackfly larvae</i>
<i>April 16</i>	
8.05 a.m.	21
8.45	21
9.05	28
9.45 treated	17
10.45	1600
11.15	3200
11.45	2400
12.15 p.m.	2400
12.45	800
12.50	600
1.15	1000
<i>April 18</i>	
10.00 a.m.	12

Forestport, Forestport Station and Otter Lake, were sprayed from the air on April 19 and 20, 1952, with the same equipment as that used in the Town of Webb. The same dosages were applied. Because of the shape of the township, the section treated was about 18 miles long and four miles wide. The maximum distance from adjoining untreated areas was, therefore, only two miles. Ten streams checked before and after treatment showed an over-all reduction of only 63 per cent in number of blackfly larvae. This was probably due to the fact that winds were moderate to high during spraying. The area was resprayed one week later, following a plan of topical application instead of a swath pattern. The end result of the two operations was a 96 per cent reduction in larval populations (table 4).

TABLE 4

Data Showing Reduction of Blackfly Larvae in Streams Treated by Aircraft with DDT in the Forestport Area

<i>Stream</i>	<i>No. of larvae per 10 attachment units</i>	
	<i>Before treatments</i>	<i>After treatments</i>
Trib. to Pine Creek	300	0
Pine Creek	150	0
Trib. to Gulf Creek.....	200	0
Gulf Creek	1000	0
Middle Road Meadow Stream	100	10
Lower Road Meadow Stream	70	0
N. Forestport, 1st stream	150	0
N. Forestport, 2d stream	200	10
Norton Road, Otter Lake	150	rare
Pole 667, Otter Lake	50	10

SUMMARY AND CONCLUSIONS OF AIRCRAFT SPRAY SECTION

1 Calculated larval population reductions of about 85 per cent were obtained by application of 0.1 pound DDT in oil solution per swath acre with swath centers a quarter mile apart, with some supplementary spraying. Since the calculation of per cent control is based on the reduction at a series of check stations and since usually it was only the smaller streams that escaped effective treatment, the actual per cent control is considerably greater than 85 per cent.

2 When DDT solution was sprayed at the same rate with swaths an eighth mile apart, with some supplementary spraying, about 90 per cent control was obtained.

3 In mountainous areas, a regular swath pattern should be followed because of the many small, temporary streams which contain blackfly larvae. The swath pattern should be modified or supplemented by

topical spraying at obviously difficult points or points of high blackfly producing potential that may have been missed by the swaths (see point 4).

4 Special care should be taken to treat lake and pond outlets since annoying blackflies may breed in large numbers at these points.

5 Good results were obtained using a 20 per cent DDT solution. Use of more dilute solutions means more gallons applied and consequently more landings, take-offs, refills, refueling and flying time.

6 Spray should be applied from aircraft only during periods of calm, or *very low* winds. Early morning and evening are usually the best times for treatment.

THE TIMING OF STREAM TREATMENTS IN RELATION TO SPECIES DEVELOPMENT

It was concluded from data gathered in 1950 that two separate stream treatments would be necessary for satisfactory control of annoying blackflies in the Adirondacks (Jamnback, 1952). The first treatment reduces larval populations of the overwintering *Prosimulium hirtipes* and the second affects *Simulium venustum* and *S. tuberosum* larvae. The latter do not appear in streams as larvae until later in the spring.

The early spring, or *P. hirtipes*, treatment should be applied in early April in the Adirondacks as soon as possible after the spring high water. A treatment in the fall after *P. hirtipes* larvae first appear in the streams would probably not be so effective as the early spring treatment because many larvae of this species hatch during the winter and spring (Stone and Jamnback, 1955).

Several workers have mentioned that blackfly pupae are harder to kill than larvae (Prévost, 1947; Hocking *et al.*, 1949; Twinn, 1950; Hocking, 1950; and others). The early spring treatment should therefore be made before any appreciable amount of pupation. In the Adirondack work, some pupation was noted before treatment on May 3d and 4th in 1950. In 1951, treatment was made between April 29th and May 1st, but there was extensive pupation before this treatment. In order to obtain maximum effectiveness treatment was made on April 16th-20th in 1952 before any appreciable pupation of *P. hirtipes*.

In 1951 there was a limited amount of pupation before treatment in Forestport (April 20th-21st), which is located about 20 miles south and at a lower elevation than Old Forge.

The second stream treatment each year is applied to reduce the larval populations of *Simulium venustum* and *S. tuberosum*. These species probably overwinter in the egg stage. Since the eggs are relatively re-

sistant to insecticides, it is necessary to postpone treatment until the larvae appear. In streams where observations were made at intervals of approximately one week, in 1951, it was noted that *S. venustum* or *S. tuberosum* larvae were first found between May 15th and June 6th (table 5) in most of the streams. In only five of the more than 40 streams examined in 1951 were larvae of these species present before May 15th. In 1952, *S. venustum* and *S. tuberosum* larvae were found only in small numbers until May 14th or later, with the bulk of the first generation appearing in streams between May 14th and May 28th as in 1951 (table 6). In the Forestport area, *S. venustum* and *S. tuberosum* larvae were found in most of the streams as early as late April.

In 1951, most of the streams were treated for the second time between May 27th and June 1st. In 1952, the second treatment was made during the last week in May and the first week in June. These treatments probably killed the majority of *S. venustum* and *S. tuberosum* larvae in the control area. However, there was localized pupation in some streams or portions of streams before treatment. This early development was especially noticeable below large stretches of still water such as beaver dams, or lake outlets and is probably due to the higher temperatures in such situations.

TABLE 5

Dates of Appearance of First Generation *S. venustum* or *S. tuberosum* Larvae in Untreated Streams and in Streams Treated to Eliminate *P. hirtipes* Larvae in 1951

Stream	Dates of treatment for <i>P. hirtipes</i>	Date when <i>S. venustum</i> or <i>S. tuberosum</i> larvae first found
Otter Lake Inlet	none	May 15
Bottle Brook	none	May 17
High Rock Pond Outlet	none	May 17
Wheeler Creek	none	May 24
Stream LGS	none	May 25
Raquette Lake Inlet	none	June 5
Nursip Brook	none	June 26
North Branch of Indian Brook.....	April 29	May 19
Safford Pond Outlet	May 1	May 22
2d Okara Outlet	April 29	May 28
Bear Brook	May 1	May 29
Cascade Brook	May 1	June 6
Third Lake Creek	May 1	May 21
Constable Creek	May 1	May 22
Indian Brook	April 29	May 25
Pole OF 38 Stream	May 1	May 28
Salmon River	May 21	June 5
Loon Brook	May 1	0
Big Moose Lake Outlet.....	May 1	0
Bald Mountain Pond Outlet	May 1	0
Townsend Pond Outlet	May 1	0

TABLE 6

Dates of Appearance of First Generation *S. venustum* or *S. tuberosum* Larvae in Untreated Streams and in Streams Treated to Eliminate *P. hirtipes* Larvae in 1952

<i>Stream</i>	<i>Dates of treatment for P. hirtipes</i>	<i>Date when S. venustum or S. tuberosum larvae first found</i>
Bottle Brook	none	May 16
High Rock Pond Outlet	none	May 28
Wheeler Creek	none	May 16
Stream LGS	none	May 23
Raquette Lake Inlet	none	May 28
Big Otter Outlet	none	May 9
South Inlet	none	May 6
Trib. to South Inlet	none	May 6
2d Big Otter Inlet	none	May 23
1st Big Otter Inlet	none	May 23
Big Stone Stream	none	June 10
Split Rock Creek	none	April 22
Eaton Pond Outlet	none	May 6
Shaw Pond Outlet	none	May 6
N. Branch Indian Brook	April 16-20	May 23
Indian Brook	April 16-20	May 14
Cascade Brook	March 14	May 20
3d Lake Creek	April 16-20	May 15
Constable Brook	April 16-20	May 27
OF 31	April 16-20	May 23
OF 38	April 16-20	May 23
Bald Mountain Pond Outlet	April 16-20	May 16
Purgatory Creek	April 20-21	May 22
1st stream N. Forestport	April 20-21	April 23
Crystal Brook	April 20-21	April 23
Bellingtown Road 1st Stream	April 20-21	April 10
Lower Road Meadow Stream	April 20-21	May 13
Trib. to Gulf Creek.....	April 20-21	April 10
Gulf Creek	April 20-21	April 19
Inlet Pine Creek	April 20-21	April 10
Pine Creek	April 20-21	May 19
Kincaid Road Stream	April 20-21	May 22

Because of these differences there is no one time when the first generation *Simulium venustum* and *S. tuberosum* larvae are present as larvae in all of the streams. Consequently, there is no one time when a treatment can be made which will kill almost all the larvae of these species in all of the streams. Ideally, the proper method of treatment would be to treat the warmer sections of streams first and the cooler stream or parts of streams later. With volunteers making the treatments this would be difficult because they must be made during the "busy" period when the resorts are preparing for the summer. Thus

far a compromise has been made and the streams were treated when the larvae were abundant in most of the streams. Unfortunately, there would already be extensive pupation at certain sites, as mentioned above. The result was emergence of some *S. venustum* and *S. tuberosum* during the early portion of the period of annoyance of these species. A possible solution to this problem might be the use of aircraft over a period of approximately two weeks during the "critical" period. These aircraft could treat lake outlets, areas of still water in streams, and beaver dams during the first part of the period and other streams and areas of streams during the latter part of the critical period. While this method would be initially more expensive, the control would probably be much more effective and there should be less subsequent necessity for fogging, which is relatively inefficient and expensive, so that the final cost might not be much greater.

Until recently it was believed that there are several generations of *Simulium venustum* and *S. tuberosum* each year but that only the first is annoying to man. It now seems likely that what previously has been considered the single species, *S. venustum*, actually comprises two species, *S. venustum*, which is annoying to man, and *S. verecundum*, which is not annoying (Stone and Jamnback, 1955).

DURATION OF EFFECT OF STREAM TREATMENTS

Prévost (1947) reported that blackfly larvae were eliminated from streams treated with DDT (in alcohol or acetone with emulsifier added) dripped in over a 24-hour period. One year later, in April and May 1947, the same streams were re-examined and no blackfly larvae found except above the treatment point and immediately below it.

In other experiments (April and May 1947) Prévost treated streams with DDT-impregnated plaster of paris blocks, obtaining concentrations of 0.1 to 0.005 p.p.m. for 48 hours. Larvae were eliminated from these streams and did not reappear during the period of observation (June to November of the same year). Prévost reported that these streams had contained blackflies only in the larval stage. In streams containing both larvae and pupae, or eggs, larvae and pupae (June 1947) larvae reappeared a few weeks after treatment. Prévost did not mention the species of blackflies involved in this work, in the paper. Later, in correspondence with Twinn (1948), he noted that the species involved were primarily *Simulium vittatum* and *S. venustum*.

Goulding and Deonier (1950) stated that most of the streams treated at the rate of 1 pound of DDT in kerosene and xylene per acre in 1946 and 1947 had no larvae in 1948. The biologies of the species involved were not considered in relation to treatments. The predominating spe-

cies were *Simulium venustum*, *S. vittatum* and *Cnephia dacotensis* with smaller numbers of *Prosimulium hirtipes*, *P. magnum*, *S. decorum* and *S. pugetense*.

These reports seem to indicate that, under certain conditions, a single treatment may have a prolonged effect. Both Prévost, and Goulding and Deonier used relatively heavy dosages of DDT which caused extensive injury to other stream fauna. In the Adirondacks, much lighter dosages were used except in a few experimentally overdosed streams. Dosages of 0.0005 to 0.001 p.p.m. for 24 hours were considered satisfactory when DDT-impregnated plaster of paris blocks were used. When DDT solutions or emulsions were sprayed or poured into streams, dosages of 0.1 to 0.3 p.p.m. for 20 minutes were considered satisfactory. These dosages killed most of the larvae present at the time of treatment and did not cause extensive injury to other stream fauna. However, they apparently did not reduce larval blackfly populations the following year (table 7).

TABLE 7

Numbers of Blackfly Larvae in Streams Treated for Three Consecutive Years, Beginning in 1950 (Samples taken before treatment in 1951 and 1952)

Streams	Numbers of larvae*** per 10 units	
	1951	1952
Stream OF 38	30	10 —
3d Lake Creek	20	20
1st before Indian Brook	400	200
Bald Mountain Pond Outlet	300	50
Old Forge Dam	1000	1000
Split Rock Creek	20	80
Okara Pole 861	30	100
Cascade Brook	10	40
Constable Creek	50	0**
Wheeler Creek	0	30
Loon Brook	50	120
Bear Brook	100	200
Eaton Pond Outlet	—	200
2d Minnow Pond Outlet	—	30
High Rock Pond Outlet	30	0
Stream OF 31	—	140
Stream OF 3	—	375
Indian Brook (south shore)	—	125
3d Fire Trail Stream	0*	70
Gull Pond Outlet	—	50
Indian Brook	1500	1000+
North Branch, Indian Brook	100	150
Big Moose Lake Outlet	—	400
Pancake Brook	—	500
Pancake Junior Brook	—	40

* Stream treated in fall of 1950.

** Stream treated in fall of 1951.

*** Species present mostly *P. hirtipes*, *C. mutata*, with a few *S. vittatum* on dams.

The figures in table 7 indicate that there was no significant reduction in populations of overwintering blackfly larvae between 1951 and 1952 even though these streams were treated twice between sampling. However, in streams experimentally treated with heavy dosages, using DDT-impregnated plaster of paris blocks in 1950 and not treated again until late in 1952, there was apparently some carry-over from one year to the next. This is brought out in table 8.

TABLE 8

Numbers of Blackfly Larvae in Streams Treated with High Dosage of Larvicide in 1950 (Samples taken before pupation of *Prosimulium hirtipes*)

Stream	Numbers of blackfly larvae* per 10 units		
	1950**	1951	1952
Townsend Pond Inlet			
Above treatment point	60	80	80
Below treatment point	60	0	0
Townsend Pond Outlet			
Above treatment point	20	50	750
Below treatment point	20	0	0
Nursip Brook			
Above treatment point	50	—	—
Below treatment point	50	rare	0

* *P. hirtipes* and *C. mutata*.

** Before any treatment.

In most of the experimental treatments made in the Adirondacks, moderate dosages of larvicide to reduce *P. hirtipes* populations had little or no effect on the (presumably) overwintering eggs of later hatching species. Although in a few instances, when DDT-impregnated blocks were used to treat streams at moderate dosages, larvae were not found until late June, or even later in the season, they appeared in mid-May to early June in other streams (see table 1).

While the data at hand are limited they suggest that it may often be possible to treat streams once a year to control both *P. hirtipes* in the larval stage and *S. venustum* and *S. tuberosum* in the egg stage with dosages which will not cause extensive injury to other fauna. It may also be possible to treat other streams once with a single heavy dosage of insecticide where other stream fauna are not important, and thus prevent breeding for several years. This might be particularly useful in the case of the small temporary streams which produce *P. hirtipes* in large numbers and which have a limited fauna. The data presented on these points are not conclusive, and further investigation is needed.

EFFECTS OF CONTROL MEASURES ON POPULATIONS OF ANNOYING ADULT BLACKFLIES

METHODS OF ESTIMATING POPULATIONS

Many students of blackflies have mentioned the difficulties in making reliable population estimates (Prévost, 1948*b*; Wilson *et al.*, 1949; Goldsmith *et al.*, 1949; Brown, 1952). There have been three principal methods used in estimating annoying adult populations. These are the sweep count, the landing rate count and the estimation method.

The sweep count may be made in two ways. Sometimes sweeps are made continuously for a period of time, generally one minute, as in the fogging experiments described earlier in this bulletin (p. 19). The other method involves making a certain number of sweeps about the head and body, generally ten or some multiple of ten (Goulding and Deonier, 1950; Hocking and Richards, 1952).

The landing rate of flies on the front of the trousers between the waist and knee during one minute was used by Hocking and Richards (1952), Brown *et al.* (1951) and Brown (1952).

The estimation method consists of estimating the number of flies around the head after standing still or walking around slowly for a certain length of time (Prévost, 1948*b*; Wilson *et al.*, 1949). Goulding and Deonier (1950) used a modification of this method: counting the adults passing between the observer and a distant object during a period of several minutes.

Biting rates were used by Garnham and McMahon (1947) but did not prove satisfactory. They also made estimates in terms of "flyboy hours," presumably the number of flies a native "boy" could catch in one hour.

The estimation method was used in evaluating the effects of the control programs in the Adirondacks. An estimate of the number of flies flying about the head and body was made after the observer had remained in one spot for 10 minutes. Since this method is necessarily somewhat subjective, it was checked at frequent intervals by the sweep method. Ten directed, successive sweeps with a 12-inch diameter hand net were made about the head and body. The catch in 10 sweeps multiplied by 5 generally gave a good approximation of the estimated population unless there were fewer than two or more than an estimated 30 adults. Under these conditions the 10 sweeps appeared to give a less satisfactory index than the estimate of the population.

Since blackflies apparently react to slight changes in meteorological conditions and respond differently to stimuli at different times, estimates of their relative abundance must be evaluated cautiously. Momen-

tary population fluctuations complicate evaluation of control programs.

PEAK ANNOYANCE PERIODS OF DIFFERENT SPECIES

To reduce error, only data collected during the "peak periods of annoyance" for the species under study were used in evaluating results of the control programs. With this system, the highly variable counts made during the gradual buildup and decline of annoying adult blackfly populations did not complicate evaluation of the control.

To define the peak annoyance period of the most important pest species, namely, *P. hirtipes* and the *S. venustum*-*S. tuberosum* group, it was assumed that the number of annoying adults *collected* was proportional to the number *present*. More flies were collected during the worst part of the blackfly season than during periods when fewer blackflies were present. In 1951 and 1952, a special effort was made to collect in numbers proportional to the numbers of annoying flies present. The period during which approximately 90 per cent of the *P. hirtipes* females were collected was designated as their peak annoyance period. In a like manner, the period during which 90 per cent of the *Simulium venustum*-*S. tuberosum* females were collected was designated as their peak annoyance period. It was found that more than 90 per cent of the population *estimates* of *two or more annoying blackflies* were made during the peak annoyance periods as determined by *numbers* of annoying flies collected.

At the beginning of the 1950 control program, it was known that *P. hirtipes* and *S. venustum* were severe pests of man at certain times, but the relative numbers of these species and of the other annoying species, their periods of emergence and peak annoyance periods were known only vaguely. No systematic collections of annoying adults had been made in the Adirondacks during an entire blackfly season.

Data collected in 1950, 1951 and 1952 indicate that *P. hirtipes* is annoying primarily during the last two or three weeks of May and that adults of the *S. venustum*-*S. tuberosum* group are annoying from the last of May to early June. Table 9 gives, in the form of percentages of totals, the relative numbers of the major annoying species collected in the Adirondacks during the "blackfly seasons" in 1950, 1951 and 1952. Other species were found only rarely in collections of annoying adults in the Town of Webb and other areas in the Adirondacks. However, in the lower and more level Forestport area, at the southeastern edge of the Adirondacks, which is lower in elevation and more level than the Adirondacks, *C. mutata* was annoying early in the spring. *S. jenningsi* was a pest species in this area during August. It was not collected while biting but was definitely anthropophilic, landing on the face, neck, and especially in the ears.

TABLE 9

Relative Numbers of Annoying Species in Collections of Adult Blackflies in the Central Adirondacks. Each Figure Is the Percentage for That Species of the Total Numbers of All Species Collected during the Period.

Date	PER CENTS												Total no. collected		
	<i>P. hirtipes</i>		<i>S. venustum-S. tuberosum</i>		Other species										
	1950	1951	1952	1950	1951	1952	1950	1951	1952	1950	1951	1952	1950	1951	1952
May															
1-15	100		91.6	0	—	0	0	—	8.4*	22	—	59			
16-31	72.6	71.9	68.2	27.4	25.2	24.2	0	2.9	7.6*	179	345	157			
June															
1-15	17.3	3.9	4.8	80.8	94.6	93.8	1.9	1.5	1.4	208	204	161			
16-30	12.8	0	4.4	85.4	98.7	88.0	1.8	1.3	7.6**	266	155	159			
July															
1-15	5.0	1.5	0	95.0	94.1	97.2	0	4.4	2.8	21	68	37			

* Mostly *C. mutata* adults from the Forestport, N. Y. area. This species is not bothersome in the Old Forge-Big Moose area or in areas to the north of the Town of Webb. Larvae of this species and adults are, however, numerous in these areas.

** Mostly *S. jenningsi* which was occasionally annoying to humans in July and August in the Forestport area but not elsewhere in the central Adirondacks.

C. mutata was not annoying in most of the Adirondacks although larvae are present in large numbers in the spring. It was annoying at times in the Forestport area. A collection of annoying adults made on the Bozenkill near Delanson (Schenectady county) on May 11, 1952, was made up of 27 *C. mutata* and 2 *P. hirtipes*.

S. parnassum larvae were found in large numbers in Bear Brook in 1951 although they were generally rare in the Adirondacks. They were annoying near this stream, suggesting that this species may be a pest in areas where it is common.

S. vittatum is reported as a pest of humans in some areas, but the adults are rarely attracted to man in the Adirondacks. Larvae of this species are present in large numbers on dam faces, near pond outlets and below large pools.

It is evident from the information given that the streams of an area should be carefully studied in order to plan an efficient control program. A knowledge of the species present and species found to be annoying to man in each region is essential. Species show some variability in feeding habits from area to area. Whether this is due to physiological races, differences in climate, availability of favored hosts, or to the presence of similar species with different habits is not known. The best procedure in developing a control program would be to collect annoying adults during the season previous to the first control operations, noting time of emergence, peak annoyance periods and types of streams in which larvae of annoying species were found.

RESULTS OF THE TOWN OF WEBB BLACKFLY CONTROL PROGRAM

1950 (a) Control of *P. hirtipes*

In 1950, blackfly control in the Adirondacks was thought of in very general terms without regard to the species involved. Because of this, the few population estimates made during the period of peak annoyance of *P. hirtipes* were inadequate. Control of this species was accomplished by the use of DDT-impregnated plaster of paris blocks to treat streams in and around Old Forge-Thendara, Big Moose, and along the north and south shores of the Fulton Chain and by helicopter spraying for larval control over about 36 square miles of relatively inaccessible territory west of Old Forge (fig. 5). These larval control measures were carried out during the last week of April and the first week of May. The treatments were supplemented by fogging with the helicopter and the use of two truck-mounted fog applicators (Tifas). Data on *P. hirtipes* abatement are given in table 10.

TABLE 10

Estimates of *P. hirtipes* Abundance during Its Peak Annoyance Period
(May 16-31, 1950)

<i>Areas</i>	<i>Average estimated population per observation</i>
Old Forge-Thendara	0.5
Big Moose	0
Marginal	1.7
Outside of control area	11.8
Total number of observations	28

Although the figures in table 10 are based on only 28 estimates of adult populations, other notes taken during this period throughout the region confirm the fact that there was marked relief from fly annoyance inside of the control area and that flies were "very bad" outside of it.

(b) Control of *S. venustum* and *S. tuberosum*

In 1950, no attempt was made to control larvae of *S. venustum* and *S. tuberosum*. Any control of these species must be ascribed to the use of helicopter and ground fogging equipment. Adult population counts for this period are summarized in table 11.

TABLE 11

Estimates of *S. venustum* and *S. tuberosum* Abundance during Their Peak Annoyance Period (June 2—July 6, 1950)

<i>Areas</i>	<i>Average estimated population per observation</i>
Old Forge-Thendara	1.3
Big Moose	5.5
Marginal	6.8
Outside of control	5.5
Total number of observations	131

The Old Forge-Thendara area was treated by both helicopter and truck-mounted Tifa. The numerous roads in the area facilitated good coverage with the ground machine. Control in this area using only fogs was fair. The Big Moose area was not treated by helicopter during this period and the lack of roads made thorough fogging from a truck difficult. There was no apparent control in this area during the *S. venustum*-*S. tuberosum* peak period of annoyance except possibly locally for short periods.

1951 (a) Control of *P. hirtipes*

In 1951, about 90 square miles around Old Forge-Thendara, along both the north and south shores of the Fulton Chain and north and west of Big Moose were treated with DDT larvicide applied by aircraft (fig. 5). The other streams in the Big Moose area and north of Fourth Lake were treated with DDT blocks. Treatments were made during the last few days of April and the first few days of May. During that period there was appreciable *P. hirtipes* pupation in some of the warmer streams. Three truck-mounted Tifas were used to fog localized increases in annoying blackfly populations. The helicopter was not used for fogging in 1951. Population counts made during the *P. hirtipes* annoyance period are summarized in table 12.

TABLE 12

Estimates of *P. hirtipes* Abundance during Its Peak Annoyance Period
(May 16-31, 1951)

Areas	Average estimated population per observation*
Old Forge-Thendara	0.3
South Shore Fulton Chain	3.6
Big Moose	8.2
Marginal	9.0
Outside of control	6.7
Total number of observations	68

* No observations made before May 16.

Control was better than expected in the Old Forge-Thendara area since it had been thought that extensive *P. hirtipes* pupation before larviciding would reduce the effectiveness of the control measure. The good control is probably partly due to the extensive use of truck-mounted Tifas. Control in the less accessible south shore area was less effective. In the Big Moose section there was no apparent control, probably because of the late treatment, the fewer streams treated in the more inaccessible or "difficult" areas, and the lack of roads to facilitate extensive use of the truck-mounted fogging machines.

(b) Control of *S. venustum* and *S. tuberosum*

Streams were treated with DDT blocks from May 27th to June 1st to reduce larval populations of *S. venustum* and *S. tuberosum*. The reduction in larval populations is reflected in the reduced populations of annoying adults during the peak annoyance period of these species as shown in table 13.

TABLE 13

Estimates of *S. venustum* and *S. tuberosum* Abundance during Their Peak Annoyance Period (May 27—June 28, 1951)

<i>Areas</i>	<i>Average estimated population per observation</i>
Old Forge-Thendara	0
South Shore	0.5
Big Moose	1.7
Marginal	1.2
Outside of control	5.3
Total number of observations	186

Control during this period was good, especially when compared with control in the same areas in 1950.

1952 (a) Control of *P. hirtipes*

In 1952, about 175 square miles were treated with larvicide applied from aircraft during the period April 16-20 (map, fig. 6). The area treated included Old Forge-Thendara, the north and south shores of the Fulton Chain, and Big Moose Lake. In addition to these areas, about 75 square miles of the Town of Forestport were treated April 19-20 and again a week later. Population counts made during the annoyance period of *P. hirtipes* are summarized in table 14.

TABLE 14

Estimates of *P. hirtipes* Abundance during Its Peak Annoyance Period (May 6-30, 1952)

<i>Areas</i>	<i>Average estimated population per observation</i>
Old Forge-Thendara	0.4
South Shore	0.5
Big Moose	0.5
Marginal	2.1
Outside of control	11.0
Forestport	0.5
Total number of observations	112

Control during the peak annoyance period of *P. hirtipes* was excellent in all areas.

(b) Control of *S. venustum* and *S. tuberosum*

Streams in the Towns of Webb and Forestport were treated during the last week in May and the first week in June with DDT blocks. Population counts made during the annoyance period of *S. venustum* and *S. tuberosum* are summarized in table 15.

TABLE 15

Estimates of *S. venustum* and *S. tuberosum* Abundance during Their Peak Annoyance Period (June 2—July 2, 1952)

<i>Areas</i>	<i>Average estimated population per observation</i>
Old Forge-Thendara	0.3
South Shore	0.2
Big Moose	2.4
Marginal	3.6
Outside of control	17.0
Forestport	1.4
Total number of observations	187

Control during this period was excellent considering the heavy population of annoying flies outside of the control area during this period. As usual, truck-mounted Tifas fogged local "hot spots" in the Town of Webb. No fogging was done in the Forestport area.

Discussion and Summary of Control Section

Although there were no comparative numerical data on blackfly abundance prior to 1948 in the areas under consideration, numerous residents of Old Forge have described the situation which existed before the control program was instituted. It is clear that a fairly uniform high level of blackfly abundance occurred, with conditions comparable from one locality to another throughout the area.

Persons were unable to work in gardens, walk even short distances, stand outside or do any out-of-doors work in the village without being attacked by swarms of blackflies. Bleeding and raw scalps were commonplace among the children. Visitors, including entomologists, also have described these conditions as existing prior to 1948. They still exist outside of the control areas.

It may therefore be concluded that the differences in fly populations between control areas and noncontrol areas since 1948 are due to the control measures that have been practiced. Data which support these conclusions have been presented in the foregoing pages.

During the three years, 1950, 1951 and 1952, when the most detailed observations on the control operations and on the habits of the flies were made, there were frequently several different control measures under way at the same time, in a limited area, so that it was not always possible to evaluate separately the results of each in terms of adult blackfly population.

Previous to the peak annoyance period of *Simulium venustum-tuberosum* in 1950, in the areas observed, no stream treatments had been made, and the only control was fogging from the helicopter and from the truck-mounted Tifas, which was done during the period of peak annoyance. Control was fairly good where both helicopter and truck-mounted Tifas were used and where there were many roads through the area. In the area where only a Tifa was used and roads were poor, there was no apparent control, except locally and for very short periods of time.

A combined larval and adult control program was carried out during the *Prosimulium hirtipes* annoyance period in 1950. Results of the combined operations were excellent in all areas. Larval control was carried out using DDT-impregnated plaster of paris blocks; adult control by helicopter and Tifa fogging. "Blocking" for larvae combined with the use of truck-mounted Tifas for adults was carried out during the peak annoyance periods of *S. venustum* and *S. tuberosum* in 1951 and 1952. Control was good during these periods. In one area, streams were blocked in 1951 to reduce *P. hirtipes* populations, but not until after extensive pupation had occurred. Control was poor even though Tifas were used for adult control. The fact that there were few roads in this area made the Tifas of limited value.

Larviciding from the air and fogging from the ground produced excellent results in 1951 and 1952 against *Prosimulium hirtipes*.

In the Forestport area, in 1952, where the program included only larviciding from the air for control of *Prosimulium hirtipes*, and only DDT plaster block stream treatment for control of *Simulium venustum-tuberosum*, control of both species was good.

Suggestions for a practical control program. From the data and observations presented in the foregoing pages, suggestions for practical control operations have been developed. These suggestions have been assembled in the Appendix at the end of this bulletin, together with a recapitulation of certain introductory material, so that the Appendix by itself will be of use to persons interested in a control program. Mimeographed copies of this Appendix are available.

THE EFFECTS OF BLACKFLY CONTROL MEASURES ON OTHER STREAM FAUNA AND ON OTHER WILDLIFE

THE EFFECTS OF DDT ON MAMMALS, BIRDS, REPTILES AND AMPHIBIANS

Because of the toxicity of DDT, large-scale insect control operations with this insecticide have invariably aroused apprehension over the possible effects on wildlife. Many careful studies have been made of these effects. A review of pertinent literature is presented in the following paragraphs.

Effects of DDT on Mammals

Large-scale field applications of as much as six pounds of DDT per acre in solution have produced no apparent injury to mammals (Coburn and Treichler, 1946; Cottam and Higgins, 1946; Ericksen, 1947; Goodrum *et al.*, 1949; Speirs, 1949; Adams *et al.*, 1949; Mackie, 1949; Stickel, 1946, 1951). According to Mackie (1949), not until dosages of 100 pounds per acre were applied were symptoms of poisoning induced in chipmunks, mice, shrews or bats.

Effects of DDT on Birds

Dosages of DDT in solution, applied at the rate of five pounds or more per acre, or as frequently repeated slightly lower dosages, are detrimental to many species of birds (Cottam and Higgins, 1946; Hotchkiss and Pough, 1946; Robbins and Stewart, 1949, Speirs, 1949). Dosages of three pounds of DDT per acre or less apparently caused little or no injury to most birds (Cottam and Higgins, 1946; Hotchkiss and Pough, 1946; Stewart *et al.*, 1946; Ericksen, 1947; Kendeigh, 1947; Adams *et al.*, 1949; Goodrum *et al.*, 1949; Robbins *et al.*, 1951). There is some evidence that the nestlings are considerably more susceptible to insecticides than the adults (Mitchell *et al.*, 1953).

Effects of DDT on Reptiles and Amphibians

DDT in solution applied at the rate of one pound or more per acre, may, under some conditions, injure some species of reptiles and amphibians. Water snakes and amphibians in shallow pools seem to be particularly susceptible (Cottam and Higgins, 1946; Goodrum *et al.*, 1949). In other instances, however, higher concentrations have been used without apparent injury to reptiles or amphibians (Cottam and Higgins, 1946; Tiller and Cory, 1947; Stickel, 1951).

EFFECTS OF DDT ON STREAM FISH

1 Direct Effects

One pound of DDT in solution per acre is about the upper limit which can be applied to streams without extensive injury to trout (Surber, 1946; Surber and Friddle, 1946; Evendon, 1947; Adams *et al.*, 1949). Fallfish, blue-gills, common shiners, common suckers, mountain suckers and black bullheads (Adams *et al.*, 1949) are apparently somewhat more susceptible than trout.

Studies of the effects on fish populations, of stream treatment for blackfly control have also been made. Garnham and McMahon (1947) reported some killing of fish in experiments with high dosages of DDT in emulsion form (up to 35.6 p.p.m. for 30 minutes) in Kenya.

In tests in troughs, Cope, Gjullin and Storm (1947) reported that blackfly larval control was accomplished at dosages well below the limits of tolerance of the fish tested. Fingerlings of silver and king salmon exhibited the same order of tolerance as rainbow trout. Dolly Varden trout of the same size group were slightly more resistant to emulsions than rainbows. Rainbow trout were disabled by DDT applied in emulsion form at the rate of 8 p.p.m. for 15 minutes and they were killed or rendered helpless by a dosage of 12 p.p.m. for 24 hours. When DDT in solution was used, rainbow trout were not disabled by concentrations of up to 35 p.p.m. for 15 minutes.

Kindler and Regan (1949) reported that good blackfly control was obtained by applying DDT emulsifiable concentrate at the rate of 0.2 p.p.m. for 10 minutes. Small trout were only slightly affected by concentrations of 1 p.p.m. for 10 minutes, but were severely affected by concentrations of 2 p.p.m. for 10 minutes. Some larger fish were affected at 3 p.p.m. for 10 minutes; and some were killed at 5 p.p.m. for 10 minutes.

Arnason *et al.* (1949), using DDT solution with emulsifier and dye added, noted no injury to several species of fish placed in live-boxes for study during treatment of the South Saskatchewan River. It was reported that blackfly larvae were eliminated by this treatment for at least 17 miles below the point of application. In the North Saskatchewan River, which was treated with the same formulation at the rate of 0.176 p.p.m. for 15 minutes, no injury to fish was noted. However, neither were blackfly larval populations greatly affected by this treatment. In other tests, DDT apparently did not injure common river fish at concentrations as high as 25 p.p.m. for 30 minutes.

Gjullin *et al.* (1949) reported that DDT in fuel oil was completely effective against blackfly larvae at 0.4 p.p.m. for 15 minutes and was not injurious to trout at 10 p.p.m. for 15 minutes, the highest dosage

tested. Trout were unaffected by DDT-acetone solution at 0.3 p.p.m. for 15 minutes while blackfly larvae were eliminated by this treatment.

Hocking *et al.* (1949) noted no injury to fish in a stream treated at the rate of 0.176 p.p.m. for 15 minutes.

Hocking (1950) reported that jackfish (*Esox lucius*), suckers and trout did not suffer any visible or permanent injury from single dosages of DDT up to "600 p.p.m.-min." (probably 40 p.p.m. for 15 minutes) in tank tests. Some symptoms in jackfish were noted at "100 p.p.m.-min." (probably 6.7 p.p.m. for 15 minutes). The LD50 of sticklebacks was reached at "150 p.p.m. per min." (probably 10 p.p.m. for 15 minutes).

Twinn (1950) reported that 30 per cent DDT-methylated naphthalene concentrate was applied to the South Saskatchewan River at the rate of 0.39 p.p.m. for 24 minutes and 0.113 p.p.m. for 16 minutes. These concentrations killed large numbers of fish. Twinn noted that, unlike fuel oil or kerosene, this preparation was heavier than water. It was observed being carried along the bottom in droplet form. Results of analyses of stomach contents of fish killed by the treatment indicate that they had been killed by swallowing globules of the DDT concentrate.

From a comparison with the dosages of DDT used in the experiments cited above it may be concluded that the dosages used in the Adirondacks for blackfly control were so low as to be of no danger to vertebrate wildlife.

2 Indirect Effects of DDT on Fish

In evaluating the indirect effects of stream treatment on fish due to reductions in the amount of fish food present, it is necessary to know the feeding habits of the fish involved. Most of the studies of stomach contents of stream fish have been on the Salmonidae, including both trout and salmon, because they are the most important game and commercial fish in rapid streams.

Food eaten by these fish is made up, to a large extent, of arthropods. The number and kind of arthropods found in fish stomachs depend partly on the number and kind available and partly on the idiosyncracies of the fish (Leonard, 1941; Hess and Swartz, 1941; and Allen, 1941 *a, b*).

The diet changes from smaller to larger organisms as the fish increase in size (Ricker, 1934; Metzelaar, 1928, 1929; and Clemens, 1928). In studies by Ricker (1934), midges, *Canthocamptus* (a copepod), *Entomostraca*, and other smaller arthropods were found in the stomachs of small trout (about one inch); larger insects including

mayflies, stoneflies, caddisflies and some midges were found in the stomachs of larger fish (about five inches) ; crayfish and fish were found in the stomachs of the larger trout.

There are also seasonal changes in diet. In the winter almost all of the food is made up of aquatic organisms (Ricker, 1934 ; Needham, 1930 ; Lord, 1930). In the summer about half of the food is aquatic in origin and half terrestrial in origin (Lord, 1930 ; Dimick and Mote, 1934).

As these studies indicate and as Muttkowski (1929) reported, trout are "opportunists" where food is concerned. That is, a decline in one kind of food is balanced by increased consumption of other types of food. Adams *et al.* (1949) reported a change in diet of trout in a stream heavily treated with DDT, this change being due presumably to decreases in "preferred" types of food. A temporary decline in the number of arthropods of aquatic origin available as food in the spring or summer would be balanced by increased surface feeding either on arthropods of terrestrial origin or on those which migrated from other streams or lakes. On the other hand, an overdose of larvicide which greatly reduced stream arthropod populations in the fall would have an indirect adverse effect on fish since few or no arthropods other than those present in the stream would be available. This is one reason why fall treatments may be objectionable.

Some observers believe that blackfly larvae may, at times, make up a substantial proportion of the diet of fish in rapid streams (Dimick and Mote, 1934 ; Leonard, 1941 ; Allen, 1941*b* ; Idyll, 1942). Other workers report that blackfly larvae may make up only an insignificant proportion of the fish food (White, 1930 ; Chapman and Quistorff, 1938 ; Cope *et al.*, 1947 ; Gjullin *et al.*, 1949*a* ; Hocking, 1950). Differences have been noted in the number of blackfly larvae found in the stomachs of different species of trout in the same streams (Idyll, 1942) and in the stomachs of the same species in different streams (Allen, 1941*b*). Blackfly larvae have been found in large numbers in a few trout taken from a stream while other trout in the same stream had few or none (Leonard, 1941). Because of the omnivorous diet of trout, a great reduction in the number of blackfly larvae available as trout food is probably not injurious, providing that there is sufficient other food available.

THE EFFECTS OF DDT ON STREAM ARTHROPODS OTHER THAN BLACKFLY LARVAE

Literature Review

Hoffman and Surber (1945) studied the effects on invertebrate fauna of aircraft application of DDT wettable powder at the rate of

one pound of DDT per acre. Samples were taken before and after treatment both above and below the treatment point. Survival of as few as 26 per cent of the invertebrates was noted in some areas. Immature Trichoptera, Ephemeroptera and coleopterous adults (Elmidae) were found to be susceptible while most of the large carnivorous Plecoptera naiads, Elmidae larvae and immature Megaloptera were not affected. No Odonata naiads were collected in stream samples before treatment but a few were collected in samples taken after treatment. Samples of the organisms carried downstream indicated that 90 per cent of the affected invertebrates were carried downstream during the first three hours.

According to Hoffman *et al.* (1946), riffle samples in a temporary stream indicated reductions of as high as 92 per cent of the invertebrate fauna of a stream treated by aircraft with 4-5 pounds of DDT per acre. In a larger stream (10 feet wide and 10 inches deep), treated by aircraft with the same dosage, reductions of as high as 90 per cent of the stream invertebrate fauna were noted. A third stream (6 feet wide and 6 inches deep), treated in the same way, had reductions of up to 87 per cent of the stream invertebrate fauna. When a wide, deep stream (60 feet wide and 20 inches deep) was treated with two pounds DDT solution per acre applied by aircraft, there was no reduction which could be attributed to DDT.

Hoffman and Merkel (1948) reported that samples taken in streams treated in 1945 with one pound of DDT solution indicated a 90 per cent reduction in invertebrate fauna a short time after treatment. One year later there was still a 39 per cent reduction. Annelids, Mollusca, Odonata, Coleoptera, Hydracarina and Megaloptera were little affected. Plecoptera, Diptera, Ephemeroptera and some Trichoptera were severely affected. A stream treated by aircraft with one pound of DDT, in solution, per acre, showed a maximum population reduction of 94 per cent. The stream was 7 to 15 feet wide and varied from a few inches to several feet in depth. Another stream was sprayed with one pound of DDT, in suspension, per acre with a maximum population reduction of 74 per cent. One year later the invertebrate population was greater than it had been before treatment. This stream was then resprayed with one pound of DDT per acre, in oil solution, with a maximum reduction of 90 per cent in invertebrate fauna.

Goodrum *et al.* (1949) reported that aerial application of two pounds of DDT (probably in oil solution) per acre over tidal marshes resulted in virtually complete elimination of the abundant fiddler crabs. No immediate effect was noted on snails and mussels.

Adams *et al.* (1949) studied streams treated by aerial application

of DDT solution at the rate of one pound of DDT per acre. Stream populations were reduced from 84 invertebrates per sample before treatment to three invertebrates per sample two weeks after treatment. Five weeks after treatment three invertebrates per square foot were counted and nine weeks after treatment there were 47 per square foot. Populations in a nearby untreated stream showed no decrease during this period. In the heavily treated stream, Oligochaetes, Hydracarina, Coleoptera and Crustacea survived the treatment while Plecoptera, Ephemeroptera, Trichoptera and Diptera did not.

Savage (1949) noted that Odonata, Sialids, Mollusca, Copepoda and Cladocera were strongly resistant to stream treatment with DDT. Gerridae, Gyrinidae and some Trichoptera were more sensitive.

Blackfly control workers have studied the effects of DDT on other stream fauna at the small dosages commonly used for blackfly larval control. Garnham and McMahon (1947) treated two streams in Kenya 13 times over a six-month period with DDT concentrations which varied from 1.3 p.p.m. or less, to 35.6 p.p.m. for 30 minutes using DDT emulsion. Immediately after the final treatments only leeches, crabs and snails were found in the streams. Many types of aquatic life had returned to the treated streams three months after the last application. Aquatic arthropods found at this time included: Ephemeroptera, Odonata, Culicidae, Corixidae, Gyrinidae and Hydrometridae.

Prévost (1947*b*) noted that emulsifiable DDT, when applied to a stream at the rate of 0.1 p.p.m. for 24 hours, killed a great number of organisms other than blackfly larvae.

In a collection of detritus on the edge of a stream previously treated with DDT in solution at the rate of 0.48 pound DDT per acre, Hocking *et al.* (1949) found 2600 specimens of 37 different families of arthropods, only two of which it was desirable to kill. This included adults and immature forms, both aquatic and nonaquatic. An oil solution of DDT at a concentration of 0.1 p.p.m. for 30 minutes was applied by hand sprayer to two other streams. Cross-stream screens were used to collect insects affected by the treatment. Complete counts were not made, because of the great amount of material collected. Random counts indicated that an unusually large number of Crustacea were affected. Immature Plecoptera, Ephemeroptera, Trichoptera, Tipulidae, Simuliidae, Chironomidae, Empididae, Dytiscidae and dytiscid adults were noted in the collection.

Arnason *et al.* (1949) found that DDT solution with emulsifier added, sprayed at the rate of 0.13 p.p.m. for 36 minutes caused an 86.2 per cent reduction in arthropods other than blackfly larvae 1.25 miles downstream, and a 6.9 per cent reduction 17 miles downstream.

The population per square foot of arthropods other than blackfly larvae is given, but the method of obtaining these figures is not stated.

In field tests with caged caddisfly larvae, Gjullin *et al.* (1949a) determined that no deaths were attributable to the insecticides tested at or near the minimum dosages needed to give complete blackfly larval control. Caddisfly larvae were not injured by DDT in fuel oil applied at the rate of 10 p.p.m. for 15 minutes or 5 p.p.m. in emulsion for 15 minutes.

Hocking (1950) noted that a great variety of organisms were carried downstream into sampling screens after blackfly larval treatments, but no detailed studies were attempted.

Methods of Sampling Arthropod Stream Populations

Most stream studies have mentioned the difficulties in obtaining representative samples and in determining the size of the sampling error. Various types of samplers have been used. In deep rivers, especially those with muddy bottoms, dippers and dredges (Richardson, 1921a, 1921b, 1928), Birge-Ekman bottom samplers and box samplers (Jonasson, 1948) have been used. In shallower streams, square-foot boxes, hand screens and strainers were used by Needham (1928). Hoffman *et al.* (1946) used square-foot-area cylinders and Ide (1940) used a square-yard emergence trap.

In 1934, a group of limnologists including H. S. Davis, P. R. Needham, A. S. Hazzard and E. Surber adopted a standard method of sampling using an easily portable square foot sampler (Surber, 1937). Many workers, especially in the United States and Canada and including several whose work was cited above have since used this square foot sampler, occasionally with slight modifications. This square foot sampler is essentially similar to that used in the Adirondack studies reported in this bulletin (see figs. 8 and 9).

To take a square foot sample, the sampler was pressed firmly into the bottom of a riffle. Stones inclosed by the square foot were then examined for closely clinging organisms which were removed and counted before the stones were discarded. The remaining gravel, silt, sand or debris was then thoroughly agitated so that most of the arthropods in the square foot were washed into the net. This technique was standardized as much as possible to give comparable and consistent results.

After the organisms in the square foot were washed into the net, the sampler was removed from the stream and the organisms were washed from the net into a white enamel tray containing water. They were then picked out, while still alive, and placed in a vial containing preserving fluid. It was easier to remove the arthropods in the field while

they were still alive and moving than it was to preserve the entire contents of the net and sort the material later in the laboratory.

The use of a square foot sampler has some disadvantages. It is difficult to sample quiet pool bottoms effectively since there is insufficient current to carry the organisms into the net. It is difficult to use the sampler on soft or mucky bottoms or where there are numerous large rocks. Finally, the number of organisms collected from a single square foot sample may take many hours to sort when they are very numerous.

Qualitative Studies in the Adirondacks

The sampler described above was also used to take the "five-minute sample" described on page 47. The data from both types of sampling contributed to the qualitative studies described below.

In smaller streams, it was often possible to observe the effects of the insecticides directly.

In small temporary streams, Plecoptera of the families Leuctridae and Nemouridae were the dominant groups. Larger and more permanent streams often had Ephemeroptera, with one or more of the following genera, as the dominant group: *Ephemerella*, *Paraleptophlebia*, *Habrophlebia* or *Stenonema*. Plecoptera of the families Leuctridae, Nemouridae and Perlidae were also present in these streams in large numbers. Portions of streams just below lakes or ponds usually had Trichoptera of the families Hydropsychidae and Philopotamidae as the dominant forms, with Coleoptera of the family Psephenidae often present in relatively large numbers.

Data from square foot riffle samples taken in treated streams in 1950 and 1952 were compared to determine whether or not any gross compositional changes had occurred in streams treated three to four years in succession for control of blackfly larvae (table 16).

Data from the approximately 400 samples represented in the table indicate that no significant ordinal changes in the fauna occurred. The relatively larger numbers of Plecoptera and fewer Ephemeroptera recorded in the samples in 1950 may have been influenced by the fact that more small, temporary streams were sampled that year than in 1952.

Only in heavily treated streams was there an apparent change in composition. For instance, in Big Moose Lake Outlet (see table 17), the Neuroptera, Odonata and Decapoda were present in relatively larger numbers, at the expense of Plecoptera, Trichoptera and Ephemeroptera. In High Rock Pond Outlet, the Hydracarina appeared to be more numerous after treatment than before. These increases appeared to be not only relative but actual; more data on this point are needed.

TABLE 16

Types of Riffle Inhabiting Arthropods in Adirondack Streams,
Based on Periodic Riffle Samples

Order	Percentages of totals from all streams	
	1950	1952
Plecoptera	55.3	36.4
Ephemeroptera	10.9	27.3
Odonata	1.0	2.8
Trichoptera	16.7	14.3
Neuroptera	0.8	4.0
Coleoptera	2.6	4.1
Diptera	11.5	9.2
Lepidoptera	0.1	—
Hydracarina	0.7	1.5
Decapoda	0.4	0.4
Total number of specimens	6622	5349

TABLE 17

Types of Riffle Inhabiting Arthropods in Exceptionally Heavily Treated
Streams in 1952, Based on Periodic Riffle Samples

Order	Percentages of totals from streams named		
	High Rock Pond Outlet	Big Moose Outlet	Constable Creek
Plecoptera	70.4	13.6	10.9
Ephemeroptera	1.6	19.1	33.7
Odonata	—	5.6*	3.3
Trichoptera	5.0	28.4	14.1
Neuroptera	—	25.9*	16.3*
Coleoptera	6.3	0.9	—
Diptera	10.1	6.5	18.5
Lepidoptera	—	—	—
Hydracarina	5.6*	0.9	—
Decapoda	1.0	6.5*	—
Total number of specimens	575	324	92

* Unusually high percentages when compared with 1952 averages from all streams combined.

Riffles in Townsend Pond Inlet, a stream only two feet wide, were too small to sample by the usual method of square foot riffle samples. The stream was treated on April 29, 1950, with one DDT block. The calculated dosage was 0.01 p.p.m. for 48 hours. This was obviously a very heavy overdose for this stream. Blackfly larvae were eliminated from the treated portion of the stream and were not found in 1951 or 1952 below the treatment point. Five minutes after treatment began, Plecoptera were seen drifting helplessly in the current. They could be seen coming from their normal habitats under leaves, sticks and stones into the open. Their movements appeared to be uncoordinated and

swimming was erratic. Their bodies arched upwards and many drifted downstream venter upwards, collecting in large numbers in pools and eddies. A pool sampled April 29, 1950, before treatment had 40 arthropods per square foot. On May 1, 1950, two days after treatment, a square foot sample of pool bottom about 200 feet below the treatment point contained an estimated 16,400 arthropods, mostly Plecoptera (Leuctridae and Nemouridae), all dead or dying. These Plecoptera were found dead and decaying 11 days later. Forty-eight hours after treatment began, many tipulids were noted crawling about in the pools. Many limnophilids (order Trichoptera) had lost their cases and were lying helplessly on the pool bottom, occasionally moving their legs and twisting their bodies in a very feeble manner. Many of the smaller Trichoptera were dead in 48 hours. The larger Trichoptera, the Tipulidae and the Plecoptera were almost all dead 11 days later.

This stream, and Nursip Brook, which was intentionally overdosed, were the only streams where anything even approaching this extensive damage occurred.

Nursip Brook was intentionally overdosed on May 11, 1950, with 0.002 p.p.m. DDT emulsion for 24 hours (from one-half of a standard plaster block). Before treatment, 41 arthropods (mostly Plecoptera) were collected from a riffle one-third of a mile below the treatment point. Shortly after treatment, large numbers of Plecoptera were drifting helplessly downstream into pools. Samples taken in pools included over 300 Plecoptera per square foot. All were apparently alive although they showed symptoms of DDT poisoning. Eleven days after treatment about one-third of them were dead. Twenty-nine days after treatment many live and apparently normal Plecoptera were collected in pool samples. No arthropods except Hydracarina and Decapoda were found in riffle samples for 48 days.

The survival of so many of the insects that were affected by DDT and carried into pools is of special interest because it was previously believed that all such arthropods were either dead or dying.

In the north branch of Indian Brook, a small stream, about three feet wide and eight inches deep, very few blackfly larvae or other arthropods were seen in the current before treatment. After the aircraft larviciding on April 16, 1952 (dosage, $\frac{1}{10}$ of a pound of DDT per acre), there continued to be only small numbers of arthropods in general, although enormous numbers of blackfly larvae (see table 3, page 48) came downstream almost immediately after treatment. Many of them were carried into backwaters or settled out into the bottoms of pools. One day after treatment most of these blackfly larvae were still alive, but a day later many were dead. Five days after treatment

all the larvae that could be found were dead and mold was growing on the masses of dead larvae. In one such mass there were 134 dead blackfly larvae, and what may be especially significant, six live chironomid larvae and ten small live amphipods.

During both 1951 and 1952, other observations of streams were made at short intervals before, during and after aircraft larviciding operations to determine what insects were carried downstream. On April 30, 1951, in the small stream near pole OF 38 near Old Forge, where five-minute samples were taken at half-hour intervals for a period of three and one-half hours after aircraft spraying with DDT in oil solution at the rate of 0.017 pound per acre, of 285 specimens taken, all but five were blackfly larvae. Few organisms of any kind had been taken before treatment.

During the period of three and one-half hours after the aircraft treatment of Indian Brook on April 16, 1952, seven five-minute samples were taken. More than 10,000 organisms were collected (aliquot estimates made of large samples). All but one of these organisms were blackfly larvae.

The five-minute samples confirmed the observation that blackfly larvae are more susceptible to DDT than other stream arthropods, and thus furnished additional evidence that blackfly larvae can be cleared from streams by dosages that will not kill most other organisms.

Quantitative Studies in the Adirondacks

The numbers and types of arthropods occurring in a stream vary greatly according to the type of bottom and the type and amount of plant life present.

This variation can be offset to a great extent if, in taking samples, all are taken from a homogeneous area of the stream, that is, where the depth, rate of flow, type of bottom and other physical factors are similar. Since small pockets of leaves, a few twigs or an eddy may greatly influence the number of organisms found within the homogeneous area, the site for the sample should be chosen with care.

The fact that small arthropods may be overlooked may also cause differences in samples of the same population. This difficulty may be minimized by setting a lower size limit on the arthropods to be counted.

For quantitative comparisons, all supraneuston, blackfly and midge larvae, all pupae, and all other arthropods as small as the small stream copepods were excluded from the counts. Supraneuston were excluded because of the ease with which they could jump out of the collecting tray; blackfly larvae were excluded because of their unusual habitat preferences and "contagious" distribution; midge larvae were excluded because they ranged in size from near microscopic to large, making

selection of macroscopic fauna more subjective than desirable; pupae were excluded because of the difficulty in determining the effect of stream treatment on organisms in this stage; other organisms as small as or smaller than large copepods were excluded because of the difficulties in collecting small specimens in the field.

The degree of reliability that could be placed on any one sample as an index of arthropod populations in a homogeneous area of a stream was established by statistical analysis of 21 sets of four samples, each set being taken from a homogeneous area of a stream. The number of arthropods in each of the 21 sets of four samples is given in the following list:

0, 0, 1, 3; 1, 1, 2, 4; 1, 1, 2, 4; 3, 5, 5, 6; 6, 8, 8, 9.

7, 8, 11, 12; 7, 10, 12, 12; 9, 10, 12, 15; 13, 14, 16, 16; 14, 14, 15, 17.

16, 17, 17, 19; 13, 18, 18, 21; 17, 21, 22, 23; 15, 22, 24, 25; 19, 21, 24, 30.

19, 24, 25, 26; 20, 21, 23, 33; 23, 24, 28, 28; 23, 27, 28, 29; 33, 34, 35, 37.

43, 46, 48, 48.

The odds were 20 to 1 that a single sample taken from a homogeneous area of any stream with a population below 50 arthropods per square foot was within 5.6 of the true mean for that homogeneous area.

Although only a single sample was taken above and below the treatment point in most of the streams on any one day, the fact that samples were taken repeatedly in the same homogeneous area of stream during each summer for several years constitutes a type of replication which would reveal any unusual variation, as well as any delayed effect of the treatments.

The several methods of stream treatment that were employed have already been described. Dates of treatment, insecticides used, method of application, dosages and effects on blackfly larvae for most of the streams have been given in table 1. Descriptions of the streams were given in the paragraphs following the table. Information on the fate of the arthropods other than blackflies is presented below, in tables 18-37.

Aedes Brook. *Aedes Brook* was treated for the first time on May 29, 1950, with one-third of a block of DDT-impregnated plaster of paris (table 18).

TABLE 18

Periodic Riffle Samples of Arthropod Populations above and below
Treatment Points in Aedes Brook

Date	Number of arthropods per sample		
	Above	1 mile below	Blackfly larval control
May 27, 1950	—	44	
May 28	41	50	
May 29, treated, DDT block, 0.003 p.p.m. for 24 hrs			
May 30	24	28	GOOD
June 8	21	14	(½ mile)
June 14	21	16	
June 21	19	57	
June 27	10	—	
July 9	—	27	
Aug. 18, 1951	—	39	
April 17, 1952, treated, aircraft, 0.1 lb. DDT/swath acre			
May 1	—	53	?GOOD*
June 24	—	44	
June 24, treated, DDT sol., 1.22 p.p.m. for 20 min.			
June 26	—	19	GOOD
July 11	—	31	(½ mile)
July 23	—	29	
Aug. 15	—	33	

* Not checked before treatment.

Since the larviciding, with the possible exception of the aircraft application, was not effective in reducing populations of the highly sensitive blackfly larvae one mile below the treatment point, all changes in population at this point were considered to be due to factors other than stream treatment. The fluctuations are probably due to "normal" seasonal changes in arthropod populations such as mass emergence, mass hatching, lowering of the water level and sampling error. The population changes in this stream indicate the magnitude of population fluctuations in a "normal" stream population as determined by single square foot samples.

Wheeler Creek. Wheeler Creek was outside of the regular blackfly control area. It was first treated May 7, 1950, with half of a DDT-impregnated plaster of paris block, giving a calculated dosage of 0.0005 p.p.m. for 24 hours (table 19).

It seems probable that control of blackfly larvae was poor in 1951 and 1952 in Wheeler Creek because of the many obstructions to flow at the time of treatment. There seemed to be no significant difference between arthropod populations one mile below the treatment point in 1950, when the blackfly larvae were virtually eliminated, and the populations in 1951 and 1952 when the control was not effective at this point.

The arthropod population one-eighth of a mile below the treatment point showed an apparent decline in numbers, presumably due to treatment in 1951. At the time of treatment the stream was low. Black-fly larvae were greatly reduced for a distance of only one-half mile. The reduction in stream arthropods was temporary.

TABLE 19
Periodic Riffle Samples of Arthropod Populations above and below
Treatment Points in Wheeler Creek

Date	Number of arthropods per sample			Blackfly larval control
	Above	$\frac{1}{8}$ mile below	1 mile below	
May 7, 1950	—	—	—	GOOD
May 7, treated, DDT block, 0.0005 p.p.m. for 24 hrs				
May 11	—	—	18	
May 22	22	—	12	
May 29	—	—	14	
May 30	107	—	—	
June 9	56	—	41	
June 15	53	—	48	
June 20	17	—	50	
June 28	32	—	49	
July 6	88	—	73	GOOD
July 17	64	—	29	
Aug. 1	78	—	12	
May 17, 1951	22	—	20	
June 7	24	44	56	
June 7, treated, TDE block, 0.008 p.p.m. for 48 hrs				
June 9	32	4, 4	36	
June 18	28	4, 8	44	
June 26	120	8	40	
July 3	48	8	56	
July 12	68	—	20	POOR
July 18	32	20	36	
July 26	104	24	16	
Aug. 27	36	—	—	
June 5, 1952	27	—	50	
June 5, treated, lindane emulsif., 0.35 p.p.m. for 20 min.				
June 10	17	—	40	
June 18	48	—	57	
June 18, treated, DDT solution, 0.80 p.p.m. for 20 min.				
June 20	113	—	36	POOR
July 1	129	—	66	
July 15	89	—	24	
July 23	19	—	—	
Aug. 1	—	—	32	
Aug. 13	14	—	8	

When normal population fluctuations and the size of the sampling error are considered, the differences in numbers of arthropods above and one mile below the treatment point during these treatments do not seem to be significant. The numbers of arthropods per square foot sample taken after treatments in 1950, 1951, and 1952 are averaged in table 20.

TABLE 20

Yearly Averages of Periodic Riffle Samples of Arthropod Populations above and below Treatment Points in Wheeler Creek

Date	<i>Number of arthropods per sample</i>	
	<i>Above</i>	<i>1 mile below</i>
1950	57.4	34.3
1951	60.0	38.0
1952	61.4	37.6

High Rock Pond Outlet. High Rock Pond Outlet was outside of the blackfly control area. It was treated for the first time May 11, 1950, with one block of DDT-impregnated plaster of paris (table 21). Blackfly larvae were eliminated from the stream even though the water was low at the time of treatment, and obstruction to flow was correspondingly high.

The arthropod populations above and below the treatment point, as indicated by an average of all the square foot samples taken after treatment each year, are given in table 22.

Arthropod populations above and one mile below the treatment point were similar in 1951, the year that blackfly larval control was not effective in this stream. The arthropod populations in 1950 and for part of 1952 were apparently reduced by the treatment. It should be noted that the dosage used in the 1952 treatment with dieldrin was far in excess of that which would normally be used in control work.

Indian Brook. Indian Brook was treated with DDT solution by aircraft three years in succession. The farthest upstream treatment point was so near the source that it was not possible to take samples above the point of treatment. Square foot samples indicated no apparent reduction in arthropods due to any of the treatments individually or to combined treatments (table 23).

Other streams treated primarily with DDT solution applied by aircraft. Two small temporary streams, FT 3 and FT 4, near Indian Brook on the Big Moose fire trail were treated by aircraft on the same dates and in the same manner as Indian Brook in 1950, 1951 and 1952.

In Stream FT 3 blackfly larvae were eliminated each year. The stream had been heavily treated with a DDT-impregnated plaster of paris block in the winter of 1950. Information regarding the date of treatment and the dosage involved is not available. While a few samples were taken in this stream, there was no indication of decline in arthropod populations due to stream treatments (table 24).

TABLE 21

Periodic Riffle Samples of Arthropod Populations above and below
Treatment Points in High Rock Pond Outlet

Date	Number of arthropods per sample				Blackfly larval control
	Above	$\frac{1}{8}$ mile below	1 mile below	$1\frac{1}{4}$ mile below	
May 11, 1950	—	—	7, 13	—	GOOD
May 11, treated, DDT block, 0.001 p.p.m. for 24 hrs	—	—	8	—	
May 22	9	—	—	12	
May 29	37	—	6	5	
June 5	18	—	7	—	
June 9	37	—	—	9	
June 15	37	—	14	9	
June 20	19	—	3	9	
June 28	58	—	10	16	
July 6	46	—	7	4	
July 17	24	—	9	11	POOR
Aug. 1	63	—	16	8	
Dec. 28	—	—	20	—	
April 8, 1951	8	—	—	—	
May 17	17, 21, 22, 23	—	22	—	
May 24	24	—	23, 27, 28, 29	—	
May 24, treated, TDE block, 0.003 p.p.m. for 48 hrs	—	—	—	—	
May 26	24	15	24	—	
June 1	15	8	18	—	
June 7	15, 22, 24, 27	17	16	—	
June 18	13	3	28	—	GOOD
June 26	13	5	19	—	
July 3	32	8	24	—	
July 11	22	10	37	—	
July 18	31	13	39	—	
July 25	50	12	43	—	
Aug. 24	26	17	18	—	
June 18, 1952	19	—	103	—	
June 18, treated, dieldrin, 1.36 p.p.m. for 20 min.	—	—	—	—	
June 20	106	—	4, 3	—	
July 2	99	—	6	—	
July 15	83	—	10	—	
July 30	44	—	12	—	
Aug. 13	26	—	11	—	

TABLE 22

Yearly Averages of Periodic Riffle Samples of Arthropod Populations
above and below Treatment Points in High Rock Pond Outlet

Date	Number of arthropods per sample	
	Above	1 mile below
1950	33.3	10.8
1951	24.8	26.6
1952	71.6	8.6

TABLE 23

Periodic Riffle Samples of Arthropod Populations below
Treatment Points in Indian Brook

<i>Date</i>	<i>Number of arthropods per sample</i>	<i>Blackfly larval control</i>
April 30, 1950	41	
May 3	64	
May 3, treated, aircraft, DDT solution 0.1 lb./swath acre		GOOD
May 9	43	
May 20	18	
May 30	10	
June 8	48	
June 14	8	
June 27	45	
Aug. 3	60	
April 29, 1951	10	
April 29, treated, aircraft, DDT solution, 0.1 lb./swath acre		GOOD
May 15	11	
May 31	33	
June 8	24	
June 22	20	
July 2	23	
April 12, 1952	78	
April 17	38	
April 17, treated, aircraft, DDT solution 0.1 lb./swath acre		GOOD
April 21	44	
May 3	28	
May 14	29	
May 23	21	
May 27, treated, lindane emulsif., 0.034 p.p.m. for 20 min.		POOR
May 29	44	
May 29, treated, lindane emulsif., 0.068 p.p.m. for 20 min.		POOR
May 31	18	
June 9	36	
June 24	16	
July 11	16	
July 23	19	
Aug. 14	235	

TABLE 24

Periodic Riffle Samples of Arthropod Populations below
Treatment Points in Stream FT 3

<i>Date</i>	<i>Number of arthropods per sample</i>	<i>Blackfly larval control</i>
April 30, 1950	15	
May 3, treated, aircraft, DDT solution, 0.1 lb./swath acre		GOOD
Dec., treated, DDT block, dosage unknown		?GOOD*
April 29, 1951, treated, aircraft, DDT solution, 0.1 lb./swath acre		none present
May 15	29	
April 12, 1952	88	
April 17, treated, aircraft, DDT solution, 0.1 lb./swath acre		GOOD
April 21	50	
May 14	22	

* No samples taken before treatment.

In nearby Stream FT 4, both in 1950 and in 1951, aircraft treatment failed to reduce blackfly larval populations. It seems likely that this was due to the small size of the stream and the fact that it ran parallel to and halfway between swaths. On March 15, 1952, 0.5 pound of 3 per cent DDT dust was applied on the snow with a hand duster in a strip 100 feet long and 13 feet wide along each bank of the stream. At the time of application, the snow was over two feet in depth. On April 12th the snow was still one foot deep along the margins of the stream, but it was almost gone by April 16th, the date of aerial application of larvicide. There was no apparent reduction in blackfly larval populations until after the aerial application of DDT (table 25).

TABLE 25
Periodic Riffle Samples of Arthropod Populations below
Treatment Points in Stream FT 4

<i>Date</i>	<i>Number of arthropods per sample</i>	<i>Blackfly larval control</i>
April 30, 1950	17	
May 3, treated, aircraft, DDT solution, 0.1 lb./swath acre		POOR
May 3	13	
April 29, 1951, treated, aircraft, DDT solution, 0.1 lb./swath acre		POOR
March 15, 1952, treated, DDT dust on snow, 0.5 lb. 3%		POOR
April 17, treated, aircraft, DDT solution, 0.1 lb./swath acre		GOOD
May 3	115	

The few samples taken in this stream gave no evidence that arthropod populations were declining due to stream treatments.

Second Okara Outlet. The second Okara Outlet was treated with DDT solution by aircraft in 1950, 1951 and 1952. In 1950 and 1951 there was nearly complete elimination of blackfly larvae from the stream by the airplane spray; in 1952, blackfly larvae had already been eliminated by hand spraying before treatment by aircraft. In addition to these treatments, there was an application of 2.6 ounces of 20 per cent DDT solution with a hand sprayer on November 22, 1951.

This stream was thus treated on five separate occasions. There was no apparent decline in numbers of stream arthropods, although there were fluctuations which are probably not attributable to the larvicides (table 26).

Gull Lake Outlet. Gull Lake Outlet was first treated November 3, 1951, with one DDT-impregnated plaster of paris block, and again on April 4, 1952, by hand sprayer. On the latter occasion, five ounces of 20 per cent DDT solution were applied giving a calculated dosage of 0.24 p.p.m. for 20 minutes. This treatment completely eliminated blackfly larvae from the treatment point to the junction of the stream with the Moose River a quarter of a mile away.

There was no significant reduction in arthropods attributable to the stream treatments (table 27). The decline in August is probably correlated with the normal seasonal diminution of flow of this stream. The sample taken on April 11th was shortly after the spring run-off which may have "diluted" the population.

TABLE 26

Periodic Riffle Samples of Arthropod Populations above and below
Treatment Points in Second Okara Outlet

Date	<i>Number of arthropods per sample</i>		<i>Blackfly larval control</i>
	<i>Above</i>	<i>1½ miles below</i>	
May 2, 1950, treated, aircraft, DDT solution, 0.1 lb./swath acre			GOOD
May 5	29	—	
May 6	20	—	
April 30, 1951	18	—	
May 1, treated, aircraft, DDT solution, 0.1 lb./swath acre			GOOD
May 5	7	—	
May 15	9, 11	—	
June 16	—	33, 34, 35, 37	
June 27	—	43, 46, 48, 48	
Nov. 22	59	43	
Nov. 22, treated, DDT solution, 0.1 p.p.m. for 20 min.			POOR
Nov. 23	—	50	
Nov. 24	—	26, 27	
Nov. 29	—	27	
March 26, 1952	—	54	
March 26, treated, DDT emulsif., 0.31 p.p.m. for 20 min.			GOOD
April 3	—	42	
April 17, treated, aircraft, DDT solution, 0.1 lb./swath acre			GOOD
April 22	—	30	
May 8	—	56	
May 31	—	14	
June 26	—	18	
July 11	—	16	
Aug. 8	—	25	
Aug. 19	—	81	

TABLE 27

Periodic Riffle Samples of Arthropod Populations One-fourth Mile below
Treatment Point in Gull Lake Outlet

Date	<i>Number of arthropods per sample</i>	<i>Blackfly larval control</i>
Nov. 3, 1951, treated, DDT block, 0.003 for 48 hrs		POOR
April 4, 1952	30	
April 4, treated, DDT solution, 0.24 p.p.m. for 20 min.		GOOD
April 11	15	
April 22	29	
May 8	20	
May 31	83	
Aug. 19	11	

Cascade Brook. Cascade Brook was treated experimentally by Dr. R. D. Glasgow in May 1949. He placed a DDT-impregnated plaster of paris block so as to give a dosage of about 0.001 p.p.m. for 24 hours. This resulted in no noticeable effect on arthropods or other stream fauna. A pyrethrins treatment was then made in order to reveal the population which survived the "standard" blackfly treatment. This brought down tremendous numbers of arthropods, and virtually stripped the stream of arthropod life.

The stream was also treated with DDT-impregnated blocks by volunteer workers in the routine program, once in 1950 and twice in 1951. In 1952, it was treated on March 14th with six ounces of 25 per cent DDT emulsifiable concentrate applied by hand sprayer, giving a calculated dosage of 0.29 p.p.m. for 20 minutes. It was treated again on April 18, 1952, with DDT solution applied by aircraft at the rate of 0.1 pound per swath acre. It received a third treatment June 3, 1952, when six ounces of 20 per cent lindane emulsifiable concentrate were applied with a hand sprayer, giving a calculated dosage of 0.118 p.p.m. for 20 minutes. All treatments in 1950, 1951 and 1952 greatly reduced the numbers of blackfly larvae present in the stream at the time.

Since only one square foot sample was taken before 1952 it was not possible to determine whether or not there was any year-to-year decline in arthropod populations, but by March 1952 (table 28) the arthropod population was at a level comparable to that of other streams, and remained normal throughout the season in spite of the severe treatment.

TABLE 28
Periodic Riffle Samples of Arthropod Populations below
Treatment Point in Cascade Brook

<i>Date</i>	<i>Number of arthropods per sample</i>	<i>Blackfly larval control</i>
May, 1949, treated, DDT blocks and pyrethrins emulsif., dosage unknown		
May, 1950, treated, DDT blocks, dosage unknown		GOOD
June, treated, DDT blocks, dosage unknown		GOOD
May 6, 1951	8	
March 14, 1952	20	
March 14, treated, DDT emulsif., 0.28 p.p.m. for 20 min.		GOOD
March 17	29	
March 24	38	
April 18, treated, aircraft, DDT solution, 0.1 lb./acre		none present
May 5	14	
May 24	23	
June 3	15	
June 3, treated, emulsif. lindane, 0.15 p.p.m. for 20 min.		GOOD
June 5	28	
June 19	15	
July 3	28	
July 17	17	
July 29	12	
Aug. 14	29	

Constable Creek. Constable Creek flows from Constable Pond for a distance of about two miles into Big Moose Lake. In the spring it is about 20 feet wide and a foot deep.

This stream has been treated for four years in succession with DDT plaster blocks, once in 1949, once in 1950 and twice in 1951. During the fall of 1951, Constable Pond was treated with rotenone to kill the fish in a project not related to blackfly control. A considerable amount of this insecticide probably flowed into Constable Creek. In 1952 this stream was in the area that was treated by aircraft, although no blackfly larvae were present at the time of treatment; and it was also treated once with DDT blocks.

Notwithstanding the repeated and heavy treatments, there was no apparent decline in arthropod stream population (table 29). The greatest temporary reduction in population which could be attributable to stream treatment occurred in 1951 after the second treatment. The water was lower than during the early spring treatment. Since it was the general practice to use the same number of blocks during both the early spring (high water) and early summer (lower water) treatments, the latter undoubtedly constituted a considerable overdose.

TABLE 29
Periodic Riffle Samples of Arthropod Populations below
Treatment Point in Constable Creek

<i>Date</i>	<i>Number of arthropods per sample</i>	<i>Blackfly larval control</i>
May, 1949, treated, DDT blocks, dosage unknown		—
April, 1950, treated, DDT blocks, dosage unknown		GOOD
May 2	10	
May 20	15	
April, 1951, treated, DDT blocks, dosage unknown		GOOD
May 16	11	
May, 1951, treated, DDT blocks, dosage unknown		GOOD
May 22	3, 5, 5, 6	
June 12	2	
Aug. 23	31	
Sept. 1951, treated, rotenone, dosage unknown		?GOOD*
March 22, 1952	7	
April 18, treated, aircraft, DDT solution, 0.1 lb./swath acre		none present
May 5	20	
May, treated, DDT blocks, dosage unknown		GOOD
May 27	12	
July 7	8	
July 29	12	
Aug. 14	17	

* Not checked before treatment.

Salmon River. The Salmon River was treated once in 1950, twice in 1951 and once in 1952 with DDT blocks, as part of the routine Blue Mountain Lake control program. It was also treated experimen-

tally on August 15, 1951, with DDT solution applied by hand sprayer; on July 17, 1952, with 10 ounces of 20 per cent emulsifiable lindane; and finally, on August 4, 1952, with 3.2 ounces of 50 per cent DDT dust (table 30).

The reason for the scarcity of arthropods below the treatment point on July 17, 1952, is not known. The last treatment previous to this sample was in April 1952 so that the low population is probably not attributable to stream treatment. There was no apparent decline in arthropod populations from year to year attributable to stream treatments.

TABLE 30

Periodic Riffle Samples of Arthropod Populations above and below
Treatment Point in Salmon River

Date	<i>Number of arthropods per sample</i>		<i>Blackfly larval control</i>
	<i>Above</i>	<i>1½ mile below</i>	
May, 1950, treated, DDT blocks, dosage unknown			GOOD
April, 1951, treated, DDT blocks, dosage unknown			GOOD
June 28	19, 21, 24, 30	—	
Aug. 15	14, 14, 15, 17	10	
Aug. 15, treated, DDT solution, 0.03 p.p.m. for 20 min.			GOOD
Aug. 17	30	29	
Aug. 28	20	40	
April, 1952, treated, DDT blocks, dosage unknown			GOOD
July 17	23, 23, 26, 30	0, 0, 1, 3	
July 17, treated, lindane emulsif., 0.1 p.p.m. for 20 min.			GOOD
July 19	16	7	
July 31	23	7	
Aug. 4	22	10	
Aug. 4, treated, 50% DDT dust, 3.2 oz., 0.16 p.p.m. for 20 min.			GOOD
Aug. 6	16	20	
Aug. 25	19, 24, 25, 26	7, 7, 11, 12	

Eaton Pond Outlet. Eaton Pond Outlet was treated for the first time on May 24, 1950, with DDT blocks. The populations of arthropods above and below the treatment point are not strictly comparable (table 31) since the treatment point was located just below a dam at Eaton Pond. The fauna below a lake or pond is usually much more numerous than further down stream, with Rhyacophilidae and Philopotamidae (order Trichoptera) especially numerous.

In 1950, the only year when samples were taken, there was little apparent change in arthropod populations due to stream treatment, except possibly for a short period at the lower check station. This reduction was temporary and may have been due to factors other than stream treatment.

TABLE 31

Periodic Riffle Samples of Arthropod Populations above and below
Treatment Point in Eaton Pond Outlet

Date	Number of arthropods per sample			Blackfly larval control
	Above	100 ft below	$\frac{1}{3}$ mile below	
May 24, 1950	35	18	20	GOOD
May 24, treated, DDT block, 0.0008 p.p.m. for 24 hrs				
May 25	—	34	48	
May 31	50	32	4, 7	
June 12	51	17	9	
June 26	34	61	147	
July 10	57	61	73	
July 20	125	—	50	
Aug. 4	232	—	29	
Aug. 28	160	—	—	

Gulf Creek (table 32). Gulf Creek was treated for the first time in 1952, when experimental stream treatment was made on March 21st with two lindane blocks, each containing one-tenth the amount of insecticide recommended for a DDT block. This treatment did not reduce the blackfly larval populations. A second treatment was made on April 4th with one DDT block. In addition, this stream was in the airplane spray plot.

There was some apparent reduction in stream arthropod population below the block treatment point. This was attributed to the blocks, since the population above the treatment point remained high even though it was in the airspray plot.

TABLE 32

Periodic Riffle Samples of Arthropod Populations above and below
Treatment Point in Gulf Creek

Date	Number of arthropods per sample		Blackfly larval control
	Above*	$\frac{3}{4}$ mile below	
March 21, 1952	46	15	POOR
March 21, treated, lindane blocks, 0.002 p.p.m. for 24 hrs			
March 25	—	16	GOOD
April 4, treated, DDT block, 0.003 p.p.m. for 24 hrs			
April 10	31	8	none present
April 19	57	8	
April 19, treated, aircraft, DDT solution, 0.1 lb./swath acre			
May 1	36	2	
May 19	9	3	
June 30	—	4	
Aug. 20	47	4	

* Below point of treatment by aircraft application.

Pine Creek. Pine Creek was treated three times in 1952 (table 33). There was a great reduction in stream populations after the first treatment. Although there was little reduction four days after treatment, the decline which was evident later was attributed partly to the treatments.

TABLE 33

Periodic Riffle Samples of Arthropod Populations above and below
Treatment Point in Pine Creek

Date	<i>Number of arthropods per sample</i>		<i>Blackfly larval control</i>
	<i>Above</i>	<i>1¾ miles below</i>	
March 21, 1952	55	84	
March 21, treated, DDT emulsif., 0.25 p.p.m. for 20 min.			GOOD
March 25	—	53	
April 19	32	4, 4	
April 19, treated, aircraft, DDT sol. 0.1 lb./swath acre			none present
April 23	17	—	
May 1	36	16	
May 19	106	7	
Aug. 4	50	20	
Aug. 4, treated, TDE emulsif., 0.20 p.p.m. for 20 min.			GOOD
Aug. 6	35	20	
Aug. 20	45	24	

Big Moose Outlet (table 34). Big Moose Outlet flows from Big Moose Lake into Dart Lake, a distance of about 1.25 miles. It is a large, permanent stream over 50 feet in width and six inches to one foot or more in depth, depending on the season. The bottom of the stream was made up of small rocks and gravel in the sampling area. There are numerous large rocks further upstream.

It was treated by volunteers once in 1949 and once in 1950, using DDT blocks, before the first bottom samples were taken. It was treated twice in the same way in 1951 and once by aircraft with DDT solution in 1952.

Although no samples were taken before treatment in 1949, it appeared that there was a considerable reduction in the number of riffle inhabiting stream organisms present after treatment in 1950 and later. It was learned in 1952, that, in addition to the treatments noted in table 34, five gallons of emulsifiable 20 per cent DDT had been poured into the stream each spring. It was also learned that all the DDT-plaster residue from making blocks was thrown into the stream. It is therefore to be expected that the stream population would have been reduced considerably by these treatments.

TABLE 34

Periodic Riffle Samples of Arthropod Populations below
Treatment Point in Big Moose Outlet

<i>Date</i>	<i>Number of arthropods per sample</i>	<i>Blackfly larval control</i>
May, 1949, treated, DDT blocks, dosage unknown		GOOD
May, 1950, treated, DDT blocks, dosage unknown		GOOD
June 20	5	
Dec. 28	6	
April, 1951, treated, DDT blocks, dosage unknown		GOOD
May 18	13, 14, 16, 16	
June, treated, DDT blocks, dosage unknown		GOOD
June 5	1	
July 13	6, 8, 8, 9	
Aug. 2	8	
Nov. 23	6	
March 17, 1952	23	
April 1, treated, DDT blocks, dosage unknown		GOOD
May 5	2	
May 20	7, 10, 12, 12	
June 19	13, 18, 18, 21	
July 18	6	
Aug. 8	16, 17, 17, 19, 20, 21, 23, 33	

Streams OF 31 and OF 38 (table 35). Two streams flowing under the South Shore Road $2\frac{1}{4}$ and $2\frac{3}{4}$ miles from Old Forge near poles OF 31 and OF 38 respectively are considered together since they were both treated in the same way at approximately the same times. These streams were treated once with DDT blocks in 1950. They were treated once by aircraft and once by blocks in both 1951 and 1952. All of these treatments were successful in eliminating or nearly eliminating larvae from the streams at the points checked.

There was no apparent injury to stream fauna from DDT solution applied by aircraft.

TABLE 35

Periodic Riffle Samples of Arthropod Populations below
Treatment Points in Streams OF 31 and OF 38

<i>Date</i>	<i>Number of arthropods per sample</i>		<i>Blackfly larval control</i>
	<i>in OF 31</i>	<i>in OF 38</i>	
May, 1950, treated, DDT blocks, dosages unknown			GOOD
April, 1951, treated, DDT blocks, dosages unknown			GOOD
May 1, treated, aircraft, DDT solution 0.1 lb./swath acre			GOOD
April 11, 1952	31	6	
April 18	32	5	
April 18, treated, aircraft, DDT solution 0.1 lb./swath acre			GOOD
May 2	36	32	
May 23	33	84	
May, treated, DDT blocks, dosages unknown		Not checked before treat-	
July 8	2	4	[ment]
Aug. 13	—	9	
Aug. 15	18	7	

Nursip Brook (table 36). There was a great decrease in the number of riffle inhabiting arthropods in this stream immediately after, and presumably due to, treatment. The number of arthropods present almost two years after treatment was still less than before treatment. However, samples in May and March may not be strictly comparable.

TABLE 36

Periodic Riffle Samples of Arthropod Populations One-half Mile below Treatment Point in Nursip Brook

<i>Date</i>	<i>Number of arthropods per sample</i>	<i>Blackfly larval control</i>
May 11, 1950	43	GOOD
May 11, treated, DDT blocks, 0.002 p.p.m. for 24 hrs		
May 12	7	
May 22	3	
May 29	3	
June 9	1	
March 26, 1952	11	

Townsend Pond Outlet (table 37). Townsend Pond Outlet was treated in 1949 by volunteers using DDT-impregnated plaster of paris blocks. It was experimentally treated on April 28, 1950, with one DDT-impregnated plaster of paris block, giving a calculated dosage of 0.005 p.p.m. for 48 hours. Blackfly larvae were eliminated from the stream below the treatment point for a distance of one mile to the point where this stream flows into Big Moose Lake Outlet.

Although only a few samples were taken from this stream, fluctuations in population did not seem to be directly related to treatments.

TABLE 37

Periodic Riffle Samples of Arthropod Populations One Mile below Treatment Point in Townsend Pond Outlet

<i>Date</i>	<i>Number of arthropods per sample</i>	<i>Blackfly larval control</i>
May, 1949, treated, DDT blocks, dosage unknown		—
April 28, 1950, treated, DDT blocks, 0.005 p.p.m. for 48 hrs		GOOD
May 4	5	
June 2	27	
Aug. 23, 1951	8	
Nov. 23	3	
March 17, 1952	6	
April 19, treated, aircraft, DDT solution, 0.1 lb./swath acre		GOOD
July 3	35	
Aug. 14	13	

Summary and Discussion of Effects of Blackfly Control Measures on Other Stream Fauna

The data cited indicate that no injury to other stream fauna need occur from blackfly larvicide properly applied at dosages that greatly reduce or eliminate blackfly larvae from the stream. Instances where injury did occur usually were traceable directly to overdosing; that is, to dosages that were considerably above those required to effect blackfly reduction.

The safest method of control was stream treatment with DDT in oil solution applied from aircraft at the rate of 0.1 pound per swath acre, with swath centers one-quarter of a mile apart. With this method and dosage, blackfly larvae were completely eliminated from most streams, while at the same time there was no observable injury to other arthropods.

When DDT-impregnated plaster of paris blocks were used, concentrations of 0.001-0.0005 p.p.m. for 24 hours greatly reduced blackfly larval populations while causing little to no reduction in populations of other stream arthropods.

When either emulsifiable concentrates or oil solutions of DDT were applied by hand sprayer or poured into a stream, dosages of 0.1 to 0.3 p.p.m. for 20 minutes (depending on the size of the stream) greatly reduced blackfly larval populations with slight or no reductions in populations of other stream arthropods.

Within the recommended ranges of dosages for treatment with DDT-impregnated plaster of paris blocks or application of DDT by hand sprayer or pouring there may be injury to other stream fauna unless the following points are remembered and appropriate precautions are observed:

Large streams (those with a flow of more than 10 cubic feet per second) require proportionately lower dosages than smaller streams.

In small streams either 0.001 p.p.m. for 24 hours using blocks, or 0.3 p.p.m. for 20 minutes by pouring, dripping or hand spraying will probably give good control without causing extensive injury to other stream arthropods. In small streams the treatment points should be closer together than in larger streams.

Medium-sized streams (10-40 cubic feet per second) may be treated with proportionately lighter dosages without decreasing the effectiveness of the control.

Large streams (over 40 cubic feet per second) may be successfully treated with DDT blocks using 0.0005 p.p.m. for 20 minutes using a hand sprayer or pouring. Higher dosages in medium or large streams may cause extensive injury to other stream fauna.

Stream treatments in the Adirondacks applied once or twice a year for three and four years over an area of more than 100 square miles had little or no apparent effect on populations of stream arthropods other than blackfly larvae. Neither the size of the arthropod population nor its composition was affected by these treatments, except in a few streams that were overdosed.

GENERAL SUMMARY AND CONCLUSIONS

Different sections of this bulletin have been summarized separately at appropriate points in the foregoing pages. The Appendix, headed "Control of Blackflies in New York," comprises specific suggestions extracted from the data presented, and may therefore be considered to include the conclusions which have been drawn.

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Note: Three important additions to the literature on blackflies were published too late for inclusion in the citations in this Bulletin. They are listed below:

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APPENDIX

CONTROL OF BLACKFLIES IN NEW YORK

Blackflies annoy man both by biting and by flying about the head and face and entering the ears, eyes, nose and mouth. Their bites may cause intense itching and be so numerous and severe as to produce headache, fever, nausea and swelling of the lymph glands. Scratching the bites may result in secondary infections.

This appendix has been prepared to give specific information for local blackfly control programs, and is available separately in mimeographed form.

Where blackflies are found. The maggot-like blackfly larvae are found in rapidly flowing streams, frequently in enormous numbers, attached to submerged rocks, sticks or trailing grass blades. They also occur on portions of dams where the water is flowing swiftly. Adult blackflies frequently swarm in for an attack when a person is raking leaves, gardening or cutting brush. Because of this, many persons conclude that they breed under dead leaves. It is often difficult to correct this entirely false impression and to convince the victims of their attacks that the flies actually breed only in running water.

Control. Control measures may be directed against the adults or the larvae. In general, larval control measures are favored in areas where blackfly control is desired for an entire season over a large area such as around summer camps and resorts. Adult control measures are favored in areas where temporary control is desired, such as along railroad tracks and roads, or in forests where men are working for short periods. As these examples suggest, larval control is effective for long periods while adult control is of short duration. In larval control, all the streams in a wide area are treated to eliminate the flies before they are on the wing. In adult control, only the immediate area where the flies are annoying is usually treated, although the wider the zone of treatment, the more effective is the control.

Larval Control by Treating Streams

Aircraft application. Aircraft application of insecticides to control blackfly larvae has certain advantages over hand application; more complete coverage can be obtained, especially in the less accessible areas; there is less danger of overdosing streams; the operation can

be completed more quickly at the proper time and can be more closely supervised.

Aircraft used. Treatment may be effectively accomplished by small planes such as Piper Cubs. Planes equipped with floats have been used advantageously in areas where there are many lakes and few landing fields.

Materials. Twenty per cent DDT *solution* has been tested extensively and has proven to be effective in reducing blackfly larval populations without causing apparent injury to other stream inhabitants when used at the low dosages recommended. Detailed studies of the effects of stream treatments for blackfly control on other organisms have been made and are reported in the section "The Effects of Blackfly Control Measures on Other Stream Fauna and on Other Wildlife," pages 65-91 in this bulletin. DDT *emulsion* is not recommended for aircraft application at the present time because it is more toxic to other organisms and has not been tested so extensively as the solution. It is sometimes more economical to buy technical (pure) DDT and solvent separately and to mix them a short time before they are used, although solutions containing 20 per cent DDT may be obtained from several chemical companies.

Spraying equipment. The spraying equipment on the plane should consist of only one or two nozzles which should emit a relatively coarse spray. If a spray plane that has been fitted for use in agricultural or forest insect work is already available, it may be adapted for blackfly larviciding by plugging all but one nozzle on each wing. The emission rate and speed of the plane should be adjusted to release one gallon of solution per flight mile; for example, one gallon per minute at 60 m.p.h. or $1\frac{1}{2}$ gallons per minute at 90 m.p.h. Because of the low dosages used, it is important that the rate of flow be constant. A pressure system is preferable to gravity or venturi flow systems. The valves should be designed so that flow can be started and stopped quickly.

Procedure. While spraying, the plane should fly 50 to 100 feet above the treetops or as low as possible depending on the pilot's judgment. The spray should not be applied when there is an appreciable breeze. The best times to spray are in the early morning or evening when there is a minimum of air movement. The basic flight pattern should be made up of parallel swaths flown one-fourth mile between centers. If possible, the pattern should be laid out so that the swaths cross most of the streams at right angles. This basic pattern may be modified where mountains or lakes make such a pattern impractical.

Large bodies of water such as lakes or ponds should not be sprayed. If 20 per cent DDT solution is applied at the rate of one gallon per flight mile, the dosage in each 100-foot swath sprayed is about $\frac{1}{10}$ pound of DDT per acre. In our experience the most successful control programs have been in areas where all the streams within five miles or more of residential centers were treated. In areas where there are only a few streams and the area to be protected is compact such extensive coverage may not be necessary.

Costs. Under favorable conditions Piper Cubs can spray about 40 flight miles an hour including loading time. It is quite simple to calculate the time and amount of spray material required to treat a given area. The number of flight miles required to spray an area for blackfly control is equal to four times the number of square miles treated.

For example, to treat 100 square miles it would be necessary to spray 400 flight miles. This would require about 10 hours flying time. At \$50 an hour it would cost about \$500 for a single application excluding the cost of materials. If the DDT and solvent are purchased separately the cost per gallon of 20 per cent DDT solution would be about \$1 (in 1954), excluding the cost of mixing. A total of about 400 gallons would be needed for a single treatment. The number of treatments required each year depends on the species of blackflies present in the area being treated. In most parts of New York, where blackflies are a problem, at least two treatments a year are necessary for adequate control. Therefore the total cost for blackfly control using aircraft would be about \$1800 for two treatments over 100 square miles. The costs vary considerably and the figures given are only approximations. In some cases it may be advisable to spray considerably more than 100 square miles and in others, it may be possible to obtain adequate control by spraying less than 100 square miles.

If fog machines or mist blowers are used as a supplementary measure for controlling the adult blackflies the over-all cost figures will, of course, be increased accordingly.

Results. If the treatments are applied under the conditions described in this circular at the proper times and using the dosages recommended, a reduction of at least 85 per cent in larval populations of the principal biting species (*Prosimulium hirtipes*), the early spring pest, may be expected. Control of this species, which overwinters in the larval stage, was very consistent in the Adirondacks when streams were treated in mid-April before the larvae enter the relatively resistant pupal stage.

Control of the later biters (*Simulium venustum* and *S. tuberosum*) by aircraft spraying has not been as uniformly successful. This may be due to several factors. First, these species overwinter in the egg stage and the eggs hatch at different times in different streams. There is no one time when the streams can be treated to kill all the larvae of these species. Some of the larvae in the warmer streams pupate before the first larvae appear in the cooler streams. Therefore it becomes necessary to treat the warmer streams earlier (about mid-May) and the cooler streams later (late May) or, as a compromise, to pick a time when the most larvae are present in the streams obtaining partial control. A second factor making control of these species more difficult is the appearance of foliage in the woods by the time the second treatment is applied. The foliage hinders penetration of the insecticide making control from the air at this time less effective. In view of the difficulty in getting as good coverage in the second spray as in the first, the use of DDT-impregnated plaster blocks for the second treatment has been practiced in some areas and for certain streams. The recent development of techniques using granular insecticides to penetrate foliage more effectively may help solve this problem and is being investigated.

Hand application. In areas where funds for aircraft application are not available, but where there are volunteers or town employees who can do the work, hand application methods may be used. In localities where the streams are readily accessible and not too numerous, hand application of insecticides may be just as satisfactory and less expensive than application by airplane. Several methods have been used in both experimental treatments and in large scale control programs.

DDT-impregnated plaster of paris blocks. The use of plaster blocks containing DDT was the first method used on a large scale in the Adirondacks. Its simplicity caused it to become popular in a number of communities. In the plaster block method of stream treatment, DDT is released slowly into the stream from a gradually disintegrating block. It is important to place these blocks in swiftly flowing water since they release the insecticide by disintegration rather than by dissolving. Properly placed blocks should disintegrate completely in 24-48 hours. *A block placed in still water will not kill blackfly larvae.* Since blocks are placed in streams during a period when water levels are fluctuating, special care must be taken to tie the block in a spot where changes in the water level will not leave it stranded out of water. *A block out of water will not kill blackfly larvae.* Directions for making the blocks are given at the end of this appendix.

Hand spraying or pouring. The insecticide may be applied directly to the stream if suitable precautions are observed. Either emulsions or solutions may be used, although solutions are preferred because they are less likely to injure other stream animals. The treatment should be made at a turbulent point in the stream to aid in dispersion and *should take at least 15 minutes*. If the solution is released into the stream too rapidly it may be carried past the blackfly larvae so quickly that it does not affect them. In small streams, a hand spray gun is preferred. In larger streams, where larger amounts must be applied, the insecticide may be poured in provided that great care is taken to release it slowly, as mentioned above.

Dosages and points of application. Blackfly larvae are more susceptible to DDT than are the other animals found in streams and they can be effectively controlled without injury to most other fish food or to fish. The amounts of insecticide needed are very small in proportion to the total volume of water flowing by the point of application during the period of treatment. *Suggested dosages are so far below the level that would be injurious to crayfish, fish, and frogs that any injury to these organisms would be a certain indication of heavy overdosing.*

The following table, based on experiments in typical Adirondack streams, is presented for use as a guide in stream treatments by hand. The "typical Adirondack stream" which required treatment may be characterized as shallow, swift and turbulent with few areas of slow water. The table cites dosages which have proved safe and effective in the experimental work in such streams. Between the limits given there are obvious adjustments in dosages that can be made for streams of other dimensions. There are other adjustments which are not so obvious which should be made for streams that do not conform to the characterizations of the so-called typical streams. The dosages required depend on many factors including the width, depth, rate of flow, number and size of pools and obstruction to flow. Following the table are comments which should help evaluate these conditions and arrive at correct dosage estimates.

Comments and Suggestions on Stream Treatments

1 Turbulent, swiftly flowing, comparatively straight streams require the smallest dosages. Slow, placid, winding streams require proportionately more insecticide. Such streams are commonly found meandering through open meadows or alder thickets, often immediately before emptying into some pond, lake or "flow."

2 Larger streams require *relatively* less insecticide than small streams.

**Amounts of DDT Needed To Control Blackfly Larvae
in Typical Adirondack Streams**

<i>Description of stream*</i>		<i>Dosage at each treatment point</i>		<i>Distance between treatment points</i>
<i>Width in ft</i>	<i>Depth in ft</i>	<i>No. of blocks needed</i>	<i>or</i> <i>Amount of 20 percent DDT solution needed</i>	
2½	¼	¼	½ oz.	¼ mile
5	½	½	1½ oz.	½ mile
15	¾	¾	4 oz.	1 mile
30	1½	1	9 oz.	1 mile
60	4	5	50 oz.	5 miles

* Rate of flow about 2 ft. per second. Suggested dosages for the large stream are estimates made from published information.

3 The distances between treatment points in smaller streams should be less than in large streams.

4 If there are numerous pools, beaver dams or stretches of slow water, treatments at more frequent intervals are indicated.

5 Whenever possible, treat immediately below lake outlets, dams and large pools.

6 It is important to treat streams not only near the roads, where they can be reached easily, but also farther upstream and downstream. Even very small temporary streams should be treated as they are often more prolific breeders of blackflies than larger streams.

7 *All* of the blackfly producing streams in an area to be protected should be treated. Treatment of all streams within 5 miles of the population centers is a good general rule.

When to treat. In the Adirondacks, at least two treatments are recommended one in early spring and one in late spring, to control the worst biters* among the several species. The first treatment is made in mid-April, the second in mid-May, the exact dates varying according to seasonal weather conditions. Roughly, the first treatment can be made at about the time crocuses begin to bloom and the ice is just going out of the larger lakes. The second treatment should be planned for about four weeks later.

Control of Adult Blackflies

Temporary, local control of adult blackflies may be obtained with fog generators or mist blowers. DDT fogs or mists may be used alone or as a supplement to larval control programs.

* *Prosimulium hirtipes* Fries, *Simulium venustum* Say and *S. tuberosum* Lundstroem.

The following suggestions apply specifically to the larger fog machines, most of the experiments on which they are based having been made with Tifas.

- 1 Use an 8 per cent to 10 per cent DDT solution (approximately 65 pounds and 80 pounds, respectively, of DDT in 100 gallons of solution).

- 2 Operate the machine at a discharge rate of 40 gallons an hour.

- 3 Operate the transporting vehicle at a speed not to exceed four or five miles an hour.

- 4 Operate only when there is little or no wind and when the fog tends to "hug the ground." In practice, these conditions usually occur early in the morning and late in the evening. If the fog is applied under unfavorable conditions it will have little or no effect.

- 5 Do not expect "perfect" control; do not expect good control for more than a few hours, or at points more than 200 to 400 yards downwind from the route of the machine.

Under the conditions described, namely, a speed of four miles an hour, with a discharge of 40 gallons an hour using a 10 per cent solution, the material would be used at the rate of 10 gallons per mile and 8 pounds of DDT per mile traveled.

The concentration, discharge rate and speed of the vehicle can be varied in several ways provided the dosage remains at about 8 pounds of DDT per mile. For example, a 5 per cent solution discharged at 40 gallons per hour from a vehicle traveling 2 miles per hour, or a 10 per cent solution discharged at 20 gallons per hour from a vehicle traveling 2 miles per hour would also give the proper dosage.

The average size of the fog particles is smaller with the lower discharge rates, and the fog is said to be "dry." When the volume of discharge is increased the proportion of larger particles becomes higher and the fog is said to be "wet." The dry fogs carry farther but they do not wet the surfaces on which they impinge as do the particles of wet fog.

As the wetness of the fog is increased the particle size approaches that produced by mist blowers and the chances of producing a residual effect are increased. Since the solvents used in the formulation may injure vegetation, especially vegetation close to the machine, when wet fogs or mists are used, appropriate precautions should be observed.

With mist blowers an emulsion is recommended, since there is less danger of burning foliage than with straight oil solutions. The mist blower should be driven at about the same speed as the fog machines, and the total amount of DDT discharged per mile should be about the same. However, results with mosquitoes indicate that a lower percent-

age of DDT and a higher volume of liquid may be preferable. As an example a $2\frac{1}{2}$ per cent DDT emulsion discharged at the rate of 125 gallons per hour, or 25 gallons to the mile at 5 miles an hour, would give a dosage of 5 pounds of DDT per mile.

There are several makes and sizes of fog machines and mist blowers on the market. There are also fog units which can be attached to the exhaust pipes of automobiles, tractors, and other power equipment. The smaller machines have a lower output and can not be expected to give as good results for large scale work. They are cheaper and more maneuverable, however, and are useful around camps and small properties where they can be used whenever desired, whereas community-owned or contract-operated machines may be unavailable when most needed.

Directions for Making DDT-Impregnated Plaster of Paris Blocks

- 1 Make forms 12 inches square with sides $\frac{3}{4}$ inch high.
- 2 Cut notches on two opposite sides at distances of $1\frac{1}{2}$, $4\frac{1}{2}$, $7\frac{1}{2}$ and $10\frac{1}{2}$ inches from one edge.
- 3 Cut four pieces of stout twine and lay them across the mold in the notches. About a foot of twine should extend beyond the edge of the mold on one side.
- 4 For 12 blocks, a convenient quantity to mix at one time, make up a batch of DDT-plaster mixture as follows:
 - a Use $5\frac{1}{2}$ lbs of 25 per cent emulsifiable DDT solution, $2\frac{3}{4}$ lbs of water and 11 lbs plaster of paris
 - b Mix the DDT concentrate with the water, then stir in the plaster of paris, mixing thoroughly.
- 5 Pour the mixture into three forms.
- 6 Adjust twine so that it is well imbedded in plaster.
- 7 After the paste has hardened sufficiently, cut each block into four equal sections parallel to the strings. Each piece will be a block $3 \times 12 \times \frac{3}{4}$ inches with a piece of string in the middle.
- 8 Allow the blocks to harden for a few days; they are then ready for use.

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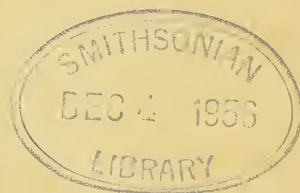
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THE ORIGIN OF
SPINEL-EMERY DEPOSITS
with Particular Reference
to Those of the
CORTLANDT COMPLEX,
NEW YORK

By
GERALD M. FRIEDMAN
Temporary Geologist



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THE ORIGIN OF SPINEL-EMERY DEPOSITS WITH PARTICULAR REFERENCE TO THOSE OF THE CORTLANDT COMPLEX, NEW YORK

By
GERALD M. FRIEDMAN
Temporary Geologist

ABSTRACT

Emery deposits in the United States are confined to the Appalachian belt in Massachusetts, New York, Virginia and North Carolina. Two types of emery are recognized, spinel-bearing and spinel-free. Besides the Cortlandt, New York, occurrence spinel-emery is found at Whittles, Virginia, and Franklin, North Carolina. Spinel-free emery occurs at Chester, Massachusetts, and Day Book, North Carolina.

An intensive study of the Cortlandt, New York, deposits was undertaken, supported by a field and laboratory examination of the Massachusetts, Virginia and North Carolina deposits. The North American emery deposits, both spinel-bearing and spinel-free, are developed in basic rocks. The uniform presence of granites or granite pegmatites close to emery bodies is conspicuous. Aplites, pegmatites or quartz veins commonly cut the basic rocks. A study of the literature and maps of foreign deposits indicates a pattern of occurrence similar to that observed in the United States, except for the spinel-free emery deposits that are developed in limestone.

Formation of the spinel-emery is explained by the reaction between the emanations of consolidating granites or granite pegmatites and pyroxene-bearing basic rocks. This reaction resulted in the formation of hornblende or biotite and the release of Fe, Mg and Al ions which gave rise to the emery. The emery occurs in irregular lenticular bodies as a replacement of the basic rock. Mg, Fe and Al ions that passed into the adjoining schist combined with the silica to form the zoned hornfels of the contact aureole. At Cortlandt the zones include: sapphirine-sillimanite zone (nearest to the norite), cordierite-sillimanite zone, kyanite-garnet-staurolite zone with sillimanite and/or cor-

dierite, quartz-garnet zone with sillimanite inclusions in the quartz (farthest from the norite).

The influence of the granites or granite pegmatites is indicated by their structural relations to the basic rocks and emery deposits, by the typical suite of minerals containing volatile constituents, by the characteristic metasomatic changes in the basic rocks that are normally ascribed to the action of granites or granite pegmatites, and, in the Massachusetts deposits, by helium age measurement.

INTRODUCTION

DEFINITION

Emery is essentially an aggregate of corundum and magnetite, but many emery bodies also contain abundant spinel, while ilmenite is likewise common. Among the accessory minerals may be mentioned hematite, hoegbomite, pyrite, sillimanite, cordierite, andalusite, staurolite and garnet.

Two types of emery are recognized, spinel-bearing and spinel-free. Although the spinel-emery may locally grade into a magnetite-corundum rock in which spinel is rare or absent, such an occurrence is uncommon. Watson (1918) introduced the term spinellite for emery in which spinel is a major constituent; however, the term spinel-emery is more descriptive and is therefore preferred. In the New York and Virginia deposits corundum-magnetite-spinel rocks (spinel-emery) grade into spinel-magnetite rocks with or without accessory corundum; to these the term spinellite is more applicable. Even this variety has been used as a commercial emery in the past.

Quarrymen today differentiate between black and gray emery. Black emery refers to the spinel-emery described above; gray emery is a cordierite-sillimanite and sillimanite-sapphirine rock, associated with the black emery deposits. Whereas the gray emery is widely quarried at present in Cortlandt Township, New York, the black emery has not been mined in the United States for at least 15 years. A garnetiferous hornfels is known to the quarrymen as red emery.

PURPOSE AND SCOPE

There is a considerable divergence of opinion concerning the origin of emery deposits. Field examination of emery deposits in North America and a survey of the literature on foreign deposits were made to find whether there exists a pattern common to all deposits which might yield a clue to the origin of the Cortlandt emery.

FIELD, LABORATORY AND LIBRARY STUDIES

Besides the New York emery deposits, occurrences in North Carolina, Virginia and Massachusetts were investigated. All of these border or are enclosed in basic rocks which appear to have been altered by younger acidic intrusives.

About 1,000 samples were collected and 220 thin sections studied. In addition, about 100 thin sections of basic rocks of Cortlandt Town-

ship and an approximately equal number of Rogers' and Butler's thin sections of emery and associated rocks in the collections of the Department of Geology at Columbia University were examined.

After the field and laboratory study of the American emery deposits was completed, an investigation of foreign deposits was made on the basis of maps and literature. The object was to determine whether foreign emery deposits are associated with the same rock types as the American. Geological maps of Scotland, Germany, Italy, Greece, Turkey, the Urals, Turkestan and Australia were examined. These show that the foreign emery is either associated with basic rocks or occurs in limestone. Younger acidic intrusives are usually present.

GEOGRAPHICAL DISTRIBUTION AND GEOLOGICAL RANGE

Emery deposits in the United States are confined to the Appalachian belt, in North Carolina, Virginia, New York and Massachusetts. The deposits of the southeastern United States are located in the Precambrian region of the Older Appalachian Province. Deposits in North Carolina are found in the Blue Ridge section in the western part of the State; those of Virginia are in the Piedmont section. The deposits of New York and Massachusetts occur in the New England Upland region of the Appalachian belt.

The emery deposits of the Appalachian belt are associated with norites, gabbros, amphibolites and probably peridotites and dunites. This belt of basic and ultrabasic rocks extends from Tallapoosa County, Alabama, to the Gaspé Peninsula on the Gulf of St. Lawrence. According to Pratt and Lewis (1905, p. 34) similar rocks again appear in western Newfoundland. The length of the belt along which these rocks occur therefore exceeds 2,000 miles.

The basic intrusions are roughly elliptical in shape. They occur at short intervals along the belt and are small in areal extent. Those of western North Carolina, according to Pratt and Lewis (1905, p. 36), are "narrow strips or small oval and lenticular masses, rarely exceeding 300 or 400 feet in width and frequently much narrower." The Cortlandt basic eruptive complex, on the other hand, underlies an area of 28 square miles.

At first glance it does not seem that all emery localities are associated with basic rocks. There is no doubt in the case of the deposits in New York and Massachusetts. A study of the Virginia and North Carolina deposits is difficult as the rocks are deeply weathered. The prevailing rock type in the vicinity of the Virginia deposits is a garnetiferous mica schist, but the emery is closely associated with basic intrusives. Watson (1923) was of the opinion that the emery

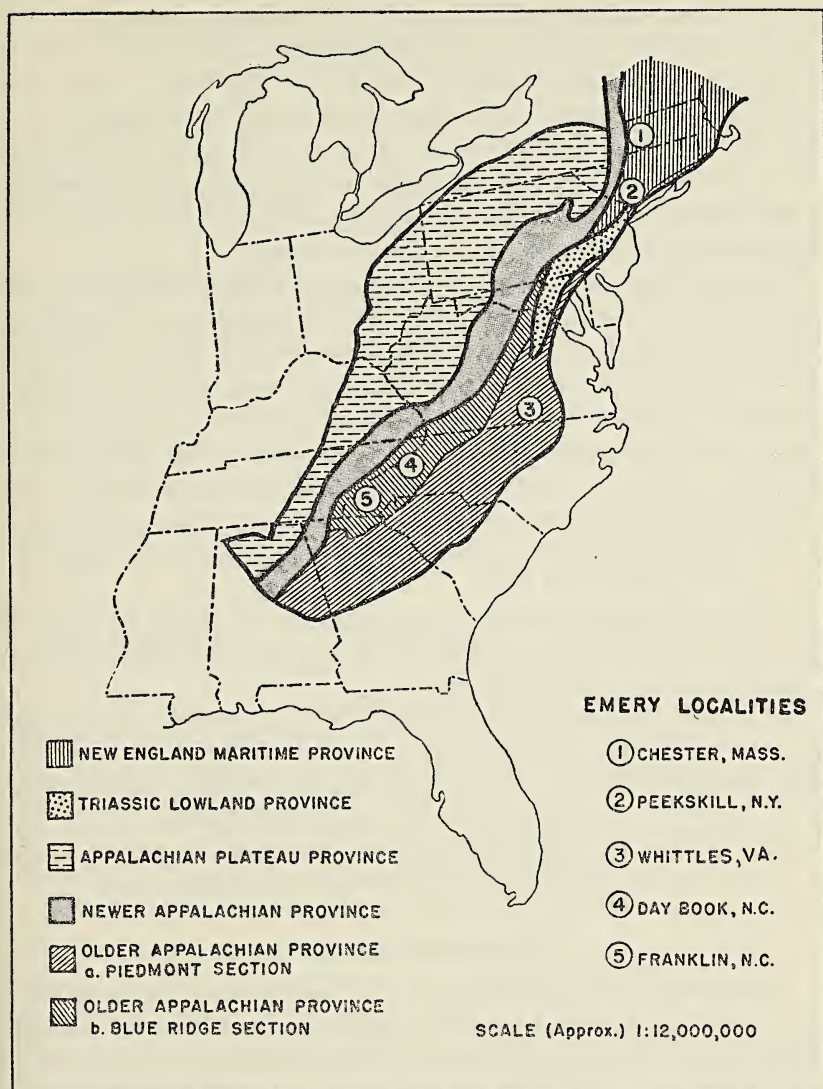


FIGURE 1.

occurred in a schist or granite, but this was not borne out by the present study.

In Macon County, North Carolina, the associated rocks are again deeply weathered. Even at a time when mining operations were in progress or had only recently ceased and the larger pits were still ac-

cessible, Pratt and Lewis (1905, p. 221) wrote that the extensive emery deposits occur in a rock so thoroughly decomposed that its exact nature remained undetermined. However, some of the deposits are associated with talc and soapstone. The peridotites of this region are normally surrounded by a mantle of talcose material, hence it seems possible that the emery is embedded in peridotite. Considering that the composition of the emery is similar to that of Virginia and New York it seems also possible that the host rock is a gabbro or norite.

The persistent association of granites or granite pegmatites with emery bodies is also conspicuous, and the granites are invariably younger than the basic rocks. Dobson Mountain and the so-called Fairview Ridge, the major emery localities in North Carolina, are surrounded by pegmatites, and pegmatite dikes occur close to the Day Book, North Carolina, deposits. The same relationship holds true in Virginia, where the emery occurs in basic rocks injected into the Wissahickon schist. The Leatherwood granite intruded the schist and basic rocks in late Paleozoic times, while dikes of aplite and pegmatite cut granite, gabbro and schist.

In New York the Cortlandt basic intrusive is adjoined in the north by the Peekskill granite. Dikes of granite and tourmaline-bearing pegmatite cut the basic complex.

In Massachusetts the Chester amphibolite is bounded to the east by serpentine, talc and emery bodies. Stocks and bosses of the Williamsburg granite occur about 2 to 2½ miles southeast of the emery. The granite is coarse-grained and is cut by pegmatites. Another granite pluton, the Middlefield granite, runs approximately parallel with the Chester amphibolite ½ or ¾ mile east of the amphibolite.

ACKNOWLEDGMENTS

Indebtedness is expressed to Dr. S. James Shand for interesting the writer in the emery problem. Sincere appreciation for valuable suggestions and friendly criticism of the manuscript is extended to Drs. Charles H. Behre, Jr., Arie Poldervaart, Frank F. Grout, Ian Campbell, Ralph J. Holmes and J. Laurence Kulp. Thanks are due to the committee of the staff of the New York State Science Service, particularly Dr. John G. Broughton, State Geologist, for the grant which made field work in Cortlandt Township possible.

The cooperation of the following property owners is gratefully acknowledged: Mr. and Mrs. Palmiotto, Messrs. Cohn and Regolinsky, Mr. De Luca, Mrs. Lättermann and Mr. Addington.

Thanks are also extended to the numerous other persons who rendered assistance in preparing this paper.

PREVIOUS HYPOTHESES DEALING WITH THE ORIGIN OF EMERY

A review of the hypotheses of emery genesis brings out evolutionary trends related to the respective period when each study was made and the locality where the investigation took place.

The discussion of the first factor is linked to the introduction of new concepts in the theory of ore genesis in general or with modification of such concepts as magmatic segregation, absorption of xenoliths, desilication of pegmatites, or contact metamorphism. At times in the past, formation of emery was attributed to processes such as those mentioned; later each explanation was discarded or modified as fashion, authority or further evidence demanded. The dawn of the era of experimental investigation is an excellent example of the influence of the prevailing fashion; although experimental science was in its infancy, the interpretation of the results obtained in the laboratory seemed to the geologist of the time to furnish the best answer to problems in the field.

The geographical location and linguistic limitations of individual investigators appear to have been the other principal factor responsible for the creation of evolutionary trends. Emery deposits of importance occur in the United States, Russia, Greece and Turkey. Four different major linguistic groups are involved in their study—English, French, German and Russian. Strange as it may at first appear, the investigator's personal background and language limitations seem to be a feature largely determining the theory accepted.

Principal lines of thought have frequently intersected and opinions long held obsolete by one group may be favored by another. The bauxite theory in which emery is regarded as the product of the dynamometamorphism of bauxite, though generally rejected by the German-speaking group since 1913, is the one at present mainly championed by French and Russian authors. In a recent Swiss publication (Oenay, 1949) this theory is revived.

In a series of papers, the last of which was published in 1946, de Lapparent (1946, pp. 227-228) maintains that emery was derived from bauxites. He believes that he can differentiate stages in the formation of emery involving the bauxites of Greece, and the emery of Naxos, Samos and Turkey. Oenay (1949) notes diaspore emery in the outer zone of the metamorphosed limestone region of the Menderes Massif of Turkey. This shows in places a pisolitic texture which is regarded as evidence of its derivation from bauxite. Closer

to the contact zone, normal emery is found. Diaspore emery is considered an intermediate product.

The belief that emery originated from bauxite agrees with the views of the early schools of Liebrig (1895), Rosenbusch (1898), Braun (1906), Grubenmann (1907) and Chautard and Lemoine (1908). Kraemer (1907), in his report on the Turkish emery, concurs with this view. He leaves it open whether regional or contact metamorphism was the active agent. Sododko (1939) claims that the deposits of the Kyzul-Kumy desert, Turkestan, are metamorphosed bauxites and extends this view to numerous deposits of the Nurantinsk and Altai mountains. He admits, however, that if his theory is correct, bauxite should occur in the Silurian limestones but so far has not been reported.

Essentially these workers relied on chemical similarity of bauxite and emery. Thus—as Liebrig (1895) pointed out—both consist of aluminum and iron oxides, the important difference between the two being the presence of water in bauxite. Further, Kraemer (1907) stated that with sufficiently high temperature and pressure bauxite can be transformed into corundum. The conformable relationship with the country rock gives the impression of a sedimentary unit which, though introducing a slight modification of the same explanation, also influenced the protagonists of the bauxite theory. The presence of pisolites in some diaspore-bearing emery deposits of Asia Minor and the Cyclades Islands has been held to be further evidence of the sedimentary nature of emery.

Papavasiliou (1914) referring to previous work by Weinschenk (1905), was the first to recognize the metasomatic influence of the adjoining body of granite which, he believed, gave off emanations rich in iron and aluminum that reacted with the country rock, a limestone, yielding the oxides that make up the Naxos emery. Mueller and Berg (1916) use the same explanation for the emery deposits of Turkey.

Transformation of laterites into emery by contact action of ultrabasic intrusives was advanced by Klemm (1916). He held that reduction in the water content of laterite was brought about by heat, increased SiO_2 content by contamination with sand and higher magnesium content by admixture with diabase tuff (schalstein).

The earliest theory on emery genesis was put forward by an American, Lawrence Smith (1850). He held that the emery deposits of Turkey were segregations from the host rock, a limestone. Williams (1887) believed that the Cortlandt emery was a result of magmatic segregation in the norite, a view which he later reversed in favor of

contact metamorphic action (Williams, 1888). Rogers (1911) regarded the emery as a product of absorption of the Manhattan schist by the Cortlandt magma. In support of this view he cited experiments performed by Morozewicz (1898). Berkey and Rice (1919), as well as Bowen (1922), are in agreement with Rogers' conclusion. Larsen (1923) favored Williams' view on the contact metamorphic origin of emery.

More recent American authors, such as Gillson and Kania (1930), as well as Butler (1936), concur with Papavasiliou in attributing emery deposits to hydrothermal emanations. The former two authors hold that emery is of contact metamorphic origin and was formed by emanations from the basic Cortlandt magma which deposited the emery in modified norite and schist. Butler, believing that the emery was formed at a much earlier stage than was previously thought, states that the emery is "believed to have been formed by emanations that were released by the magma during intrusion and these emanations passed through the country rock (Manhattan schist) only a short distance in advance of the magma. Thus, the formation of emery took place during the early liquid-magmatic stage of the basic Cortlandt intrusives" (1936, p. 538).

Ozerov (1933) suggests for emery formation a desilication process of a pegmatite magma as in the Irtash region in the Urals, where the magma intruded a limestone, amphibolite and ultrabasic complex. Gordon (1921, pp. 185-186) advances a similar hypothesis for the emery of Chester, Massachusetts.

THE EMERY DEPOSITS OF THE CORLTANDT COMPLEX, NEW YORK

LOCATION

Cortlandt Township is located to the south and southeast of the town of Peekskill, Westchester County, New York, about 35 miles north of New York City.

PREVIOUS WORK

Williams (1887, 1888) determined the mineralogical and chemical composition of the emery and Rogers (1911) made a petrographical study of the various emery types and associated country rock. Gillson and Kania (1930) and Butler (1936) investigated the emery deposits of Emery Hill and gave field and petrographic descriptions.

GENERAL GEOLOGY

The emery is associated with a basic plutonic rock complex, generally referred to as the Cortlandt Complex. The complex is elliptical in

shape, underlies an area of 28 square miles and is almost entirely surrounded by the Manhattan schist. The age of the complex is uncertain; Gillson and Kania (1930, p. 506) call it post-Ordovician, and Rogers (1911, p. 20) "more probably late Paleozoic." It is certainly younger than the Manhattan schist which may be Precambrian.

There are four major emery localities in the complex (1) in the northeast at Emery Hill, (2) at Furnace Dock Road, north of Maple Avenue (approximately in the east-central part of the complex), (3) in the southeastern part of the complex around Salt Hill, and (4) in the southwestern part of the complex at Montrose.

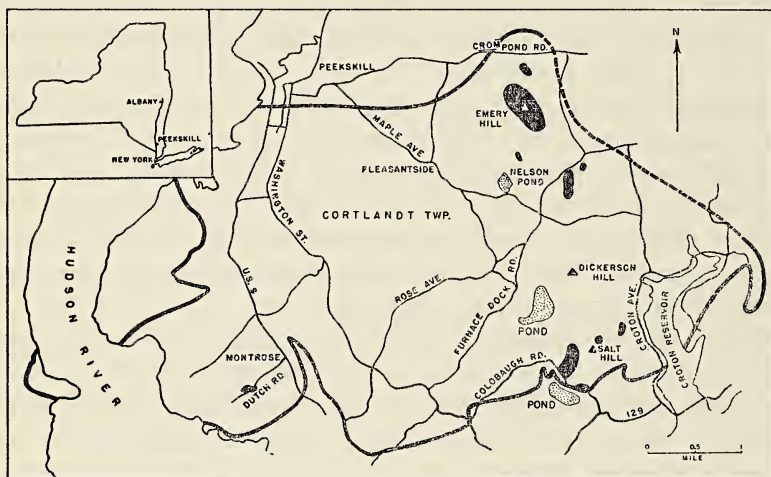


FIGURE 2. Outline map of the Cortlandt Complex, Westchester County, New York, and its included emery deposits with inset map of New York State. Solid black pattern represents emery deposits, heavy line represents outer boundary of the complex according to R. Balk.

Major rock types of the Cortlandt complex are: peridotite, pyroxenite, norite and diorite, described by Rogers (1911) and Shand (1942). The Peekskill granite which adjoins the complex to the northeast has been described by Rogers (1911, pp. 20-23).

The granite is probably younger than the complex since associated aplites, pegmatites and quartz veins cut the basic rocks. Tourmaline crystals 1 inch long occur in some of the pegmatites.

Emery deposits occur as irregularly shaped bodies; gray emery is metasomatically altered Manhattan schist, black emery, a replacement product of the basic rock.

MONTROSE DEPOSITS

Location. The deposits are located north and south of Dutch Road, southwest of U. S. Route 9. Most of the old pits have caved

and their location could not be determined. Only one pit is still accessible, located about 100 feet north of Dutch Road and about one-third of a mile southwest of U. S. Route 9.

Petrography. The emery is associated with norite, which consists mainly of labradorite and hypersthene. Poikilitic biotite is abundant and has apparently formed at the expense of labradorite and hypersthene. Many hypersthene crystals are rimmed by biotite which may also occur in the center of the crystals. Magnetite is also abundant and ubiquitous. It is usually associated with biotite and is of irregular shape.

Some magnetite crystals form a ramifying network in feldspar or pyroxene. Near the emery deposits magnetite is more abundant than elsewhere. Large portions of pyroxene crystals have been replaced by magnetite, hypersthene relics forming small islands within magnetite. Pyrite is a prominent accessory and is usually associated with magnetite.

Spinel, an accessory mineral of the norite, is usually associated with poikilitic biotite. Near the emery, spinel is again more abundant than elsewhere. Thin sections from the norite-emery borders show a gradation from norite, composed of hypersthene and labradorite with some spinel, to a spinel-magnetite rock with small amounts of corundum. In the norite near the emery border, spinel is abundant. Small replacement nuclei of spinel are found in pyroxene crystals associated with magnetite, and some hypersthene crystals may contain many such inclusions. In other crystals several spinel inclusions have coalesced and replaced a large part of the hypersthene. In the norite close to the emery-norite border, where spinel is abundant, crystals of the latter may enclose corroded hypersthene relics.

In the emery, hypersthene is still present in small amounts, either as irregularly-shaped individuals or occasionally in the polygonal form which spinel normally assumes. Replacement nuclei of spinel are usually enclosed in the hypersthene. Feldspar may show similar replacement features, but these last are not as striking in appearance as those of hypersthene. In many slides there are indications of preferential replacement of feldspar by biotite, and hypersthene by spinel. This, however, does not always hold, and relic hypersthene as well as spinel and magnetite grains have been noted in poikilitic biotite.

Near the emery deposits biotite is more abundant than elsewhere. In emery near the norite border, biotite and spinel are the major constituents, while primary norite minerals are absent or occur as relics. Biotite and spinel appear genetically related to the same stage of norite alteration.

Butler (1936, p. 543) suggested that the Montrose deposits (referred to by him as Crugers) are associated with areas of pyroxenite, as delineated by Rogers. However, examination of thin sections of the country rock in which the emery occurs indicates norite, not pyroxenite.

The emery consists predominantly of a green ferroan spinel (pleonaste) which generally amounts to about 65 percent of the rock, but the spinel content shows considerable variations. The spinel has the following composition (Rogers, 1911, p. 69): MgO 13.36 percent, FeO 21.78 percent, Al_2O_3 64.86 percent. Its refractive index is 1.775 ± 0.005 (Larsen, 1921, p. 84). The chemical formula for the spinel may be written $(\text{Mg}_{.52}\text{Fe}_{.48}) \text{Al}_2\text{O}_4$. Usually the spinel contains black opaque inclusions, probably magnetite. Magnetite, ilmenite, pyrite and hematite make up about 25 percent of the emery, but again the amount varies widely. Corundum is almost entirely lacking in some slides and nowhere exceeds 10 to 15 percent. Usually it occurs as large prismatic crystals, 3 to 6 mm. long, which may show rhombohedral partings. Many crystals contain inclusions of spinel and opaque ores. Titaniferous magnetite is commonly enclosed in spinel.

SALT HILL DEPOSITS

Location. The Salt Hill area is the second most important emery locality in Cortlandt Township. Salt Hill is located in the township's southeastern part. Deposits are found on the southwest, south and east slopes of Salt Hill as well as near its peak.

Only the Kingston Mine on Colabaugh Road¹ is at present in operation at Salt Hill. The gray emery quarried here is exposed on the north side of Colabaugh Road. About 1,000 feet northwest of the Kingston Mine, a black emery is exposed in an abandoned roadside quarry. On the slope of the hill north of the quarry are four abandoned emery pits. No further exposures were observed directly north of these but approximately 500 feet northeast of the last outcrop emery was observed again. It forms high cliffs and ridges and makes up the top of a knob southwest of Salt Hill.

The deposits of Colabaugh Road and the west and south slopes of Salt Hill are reached from Peekskill, following Washington Street south. About 4 miles southeast of the town, Colabaugh Road branches off to the east. The deposits are about $1\frac{1}{2}$ miles from here on the north side of Colabaugh Road.

The emery deposits of the peak of Salt Hill are about 200 or 300 feet south of the fire tower on the west side of a narrow trail. A small swamp or pond marks their location.

¹ Also referred to as Collaberg or Colobaugh Road.

The last two deposits can also be reached from Colabaugh Road by ascending Salt Hill from the south and following the path mentioned above.

Petrography. The wallrock of the black emery is norite, which consists essentially of labradorite and hypersthene, and in which augite is locally prominent. Poikilitic biotite is common and poikilitic hornblende is occasionally found. Spinel and opaque minerals are more abundant near emery where they replaced pyroxenes and feldspars.

In norite containing abundant poikilitic hornblende and biotite and ramifying magnetite and/or spinel crystals, the feldspars exhibit dense but patchy gray cloudiness caused by a concentration of tiny parallel rods and minute specks. Although most feldspars near emery deposits show this alteration to a varying extent, it seems most prominent where pyroxenes show widespread replacement. The degree of alteration is apparently not related to distance from the intrusive border. MacGregor (1931) explained this type of alteration as a contact-metamorphic effect. This cloudiness must not be confused with turbidity in feldspars caused by decomposition.

The emery resembles that from the Montrose deposits; however, corundum is more abundant. The corundum prisms are larger than any other constituent minerals; lengths of 3 to 5 mm. were measured along the *c*-axes. Locally sapphire is noted. It is pleochroic with absorption $O = \text{deep blue}$, $E = \text{light blue}$, $O > E$. It usually occurs toward the edges of large corundum crystals.

Small spinel crystals are enclosed in corroded hypersthene relics near norite. Biotite is occasionally associated with emery, where it was derived by replacement of primary norite minerals. Crystals of corroded labradorite similarly occur as inclusions in emery near norite.

Quartz veins cut the emery and a new suite of minerals was formed by the reaction between emery and the silica of the veins. These minerals are garnet, sillimanite, cordierite, sapphirine and andalusite. The most conspicuous of these is garnet. Garnet usually forms reaction rims bordering quartz veins. Spinel is apparently incompatible with free silica and reacted with it to form garnet. Wherever quartz and spinel occur in the same slide the two minerals are separated by a reaction rim.

The physical properties of the garnet are as follows:

Refractive index = 1.772 ± 0.002

Density = 3.91 ± 0.01

Lattice constant = $11.52\text{\AA}$.

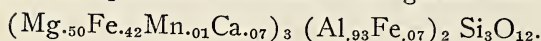
Its MnO content is 0.75 percent.

From these data the following composition has been calculated¹:

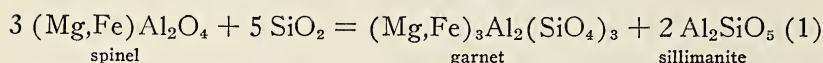
TABLE 1

<i>Mineral</i>	<i>mol percent</i>
Pyrope	50
Almandite	42
Spessartite	1
Grossularite	0
Andradite	7

The equivalent formula of the garnet solid solution is:

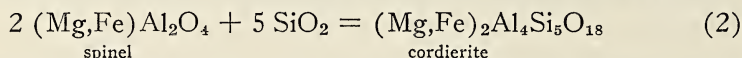


Reaction between spinel and silica may also produce sillimanite; it occurs as inclusions in quartz and garnet and forms an occasional zone between garnet and spinel or is interstitial between the spinel crystals. The reaction between spinel and silica, producing garnet and sillimanite, is expressed in the following equation:

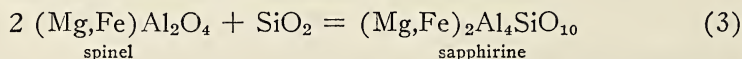


Spinel has lost its rich green color near the reaction rims and has become light-green. Green streaks of spinel occur in garnet, and islets of garnet in quartz usually contain irregular, light-green spinel nuclei.

Occasionally cordierite forms reaction rims bordering quartz veins, and garnet is absent. Its formation may be expressed by the equation:



Sapphirine is another mineral that replaced spinel near quartz veins. The reaction involved is represented by the equation:



Three definite zones bordering the quartz veins are apparent: garnet plus sillimanite, sapphirine, spinel. Locally, cordierite rather than garnet plus sillimanite forms reaction rims bordering quartz veins and then the zoning is as follows: quartz, cordierite, sapphirine, spinel. The zoning is one of decreasing silica and increasing magnesium-iron content. The ratio of silica to magnesium-iron oxides is 5 to 2 in cordierite, 5 to 3 in garnet and sillimanite and 1 to 2 in sapphirine.

¹ The garnet composition has been calculated by Dr. S. B. Levin.
MnO and density determinations were made by S. S. Goldich.

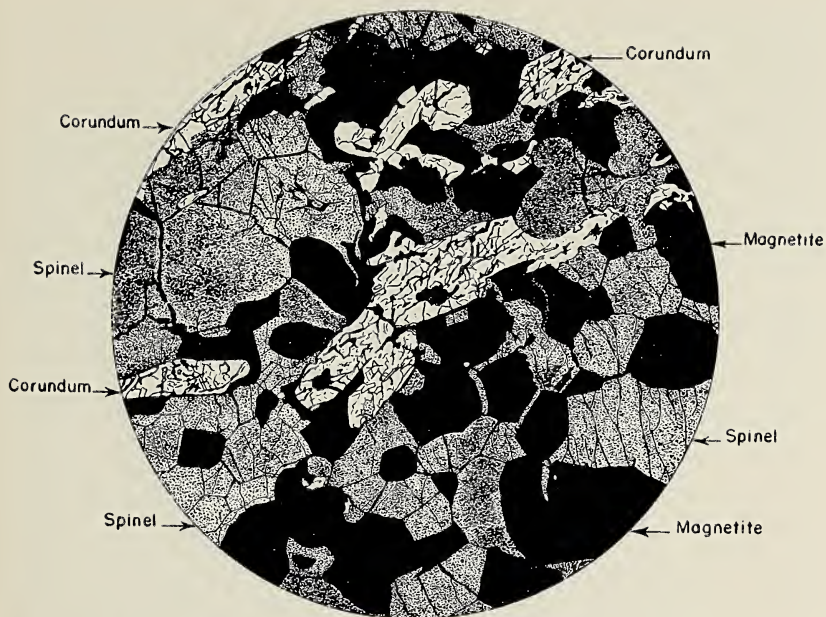


FIGURE 3. Spinel emery showing characteristic aggregate of spinel, corundum and magnetite. Salt Hill deposit. Plane light. 29.6 X.

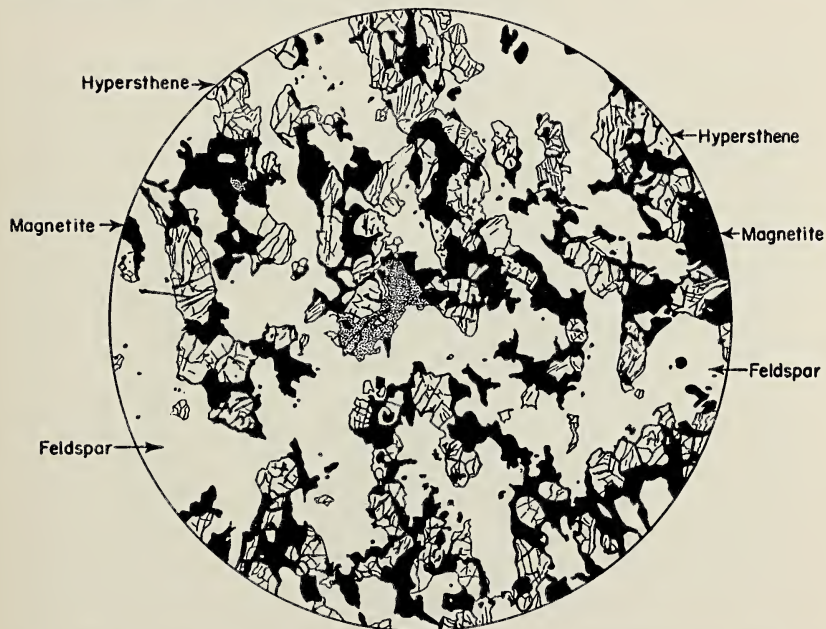


FIGURE 4. Norite showing partial replacement by emery minerals. Spinel grains (stippled; approx. in center) have replaced hypersthene and enclose a corroded hypersthene grain. Magnetite shows similar replacement features. Salt Hill deposits. Plane light. 29 X.

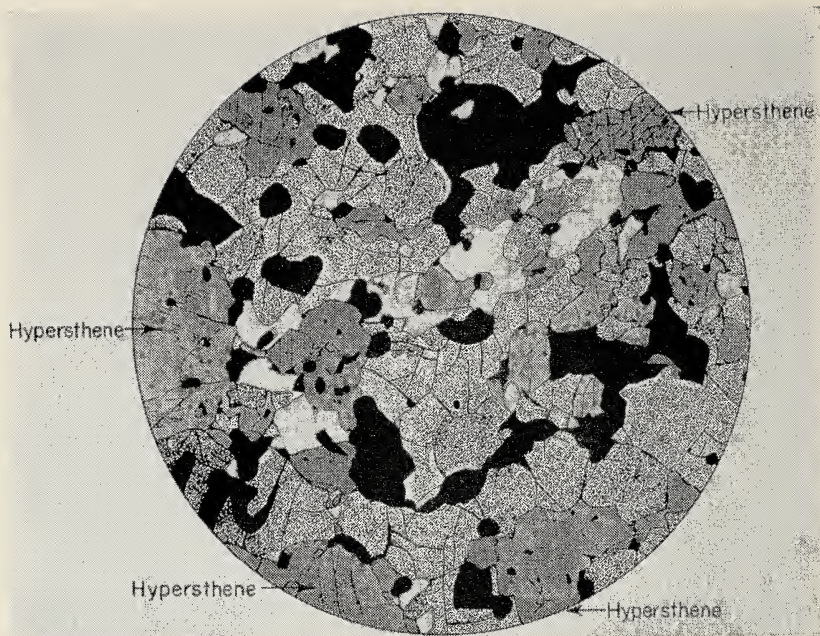


FIGURE 5. Advanced stage of norite replacement. Spinel (stippled) and magnetite (opaque) have replaced hypersthene and feldspar (white). Replacement nuclei of spinel in hypersthene. Salt Hill deposit. Plane light. 76.5 X.

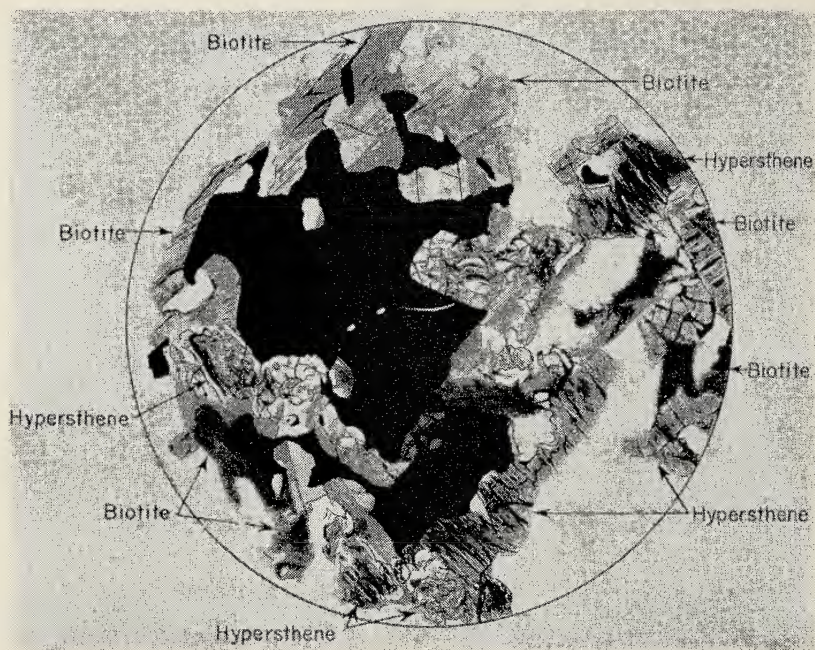
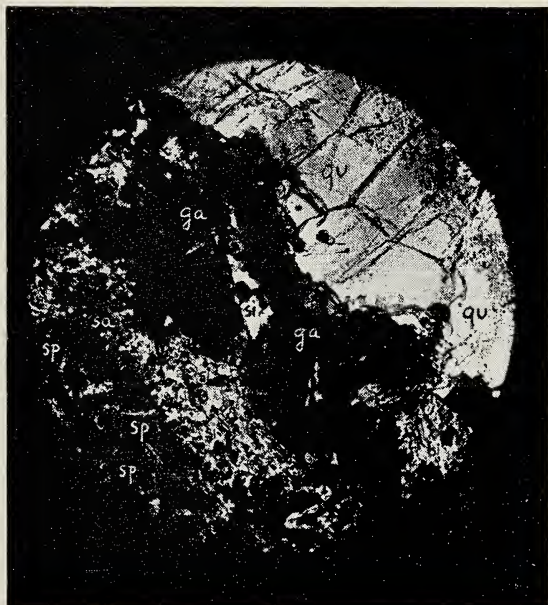


FIGURE 6. Norite in which poikilitic biotite and magnetite have replaced hypersthene and feldspar (white). Salt Hill deposit. Plane light. 69.2 X.



FIGURE 7.
Spinel relics (sp)
in quartz (qu) bor-
dered by reaction
rims of garnet. Sil-
limanite needles in
quartz. Plane light.
150 X.

FIGURE 8.
Reaction rims bor-
dering quartz vein.
qu—quartz
ga—garnet
si—sillimanite
sa—sapphirine
sp—spinel.
Crossed nicols.
45 X.



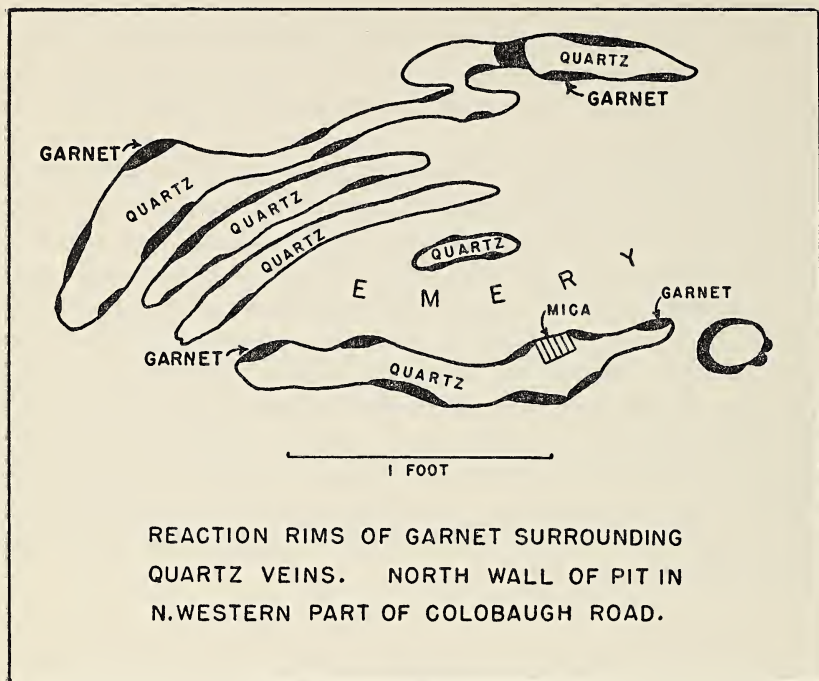


FIGURE 10

Andalusite is probably a replacement product of corundum. Corroded corundum crystals are surrounded by andalusite which spreads like a fungus through the former. The equation is: $\text{Al}_2\text{O}_3 + \text{SiO}_2 = \text{Al}_2\text{SiO}_5$. Sillimanite appears to have similarly formed as a replacement of corundum. Sillimanite is much more abundant than andalusite.

Labradorite crystals enclosed in emery have been altered to oligoclase or andesine near quartz veins. Plagioclase crystals are either devoid of twinning or show only faint lamellae.

Hoegbomite as a replacement product of spinel was noted locally. Gillson and Kania (p. 518) recognized the secondary origin of hoegbomite; Butler (p. 547) considered it as belonging to the same stage of emery development as spinel, magnetite and corundum.

Locally, biotite forms reaction rims bordering quartz veins; occasionally such a vein is bounded at one side by mica and at the other by garnet.

The rock quarried in the Kingston Mine on Colabaugh Road is a gray emery. It is dense, tough and has a hardness of about $7\frac{1}{4}$. It is essentially a cordierite-sillimanite rock with varying amounts of magnetite, and it contains accessory biotite. Under the microscope, cor-

dierite stands out because of its yellow pleochroic haloes surrounding zircon inclusions.

Norite, which forms the north wall of the Kingston Mine, contains spinel and magnetite. Near norite the gray emery is a sapphirine-sillimanite-magnetite rock. This forms a narrow zone. With increasing distance from the norite, cordierite appears and becomes abundant, taking the place of sapphirine. Cordierite-sillimanite-magnetite rock forms the next zone and is followed by cordierite-sillimanite rock containing less magnetite. There is a corresponding decrease in magnetism with increasing distance from the norite and a color change from black to gray. Vertical zoning is similar, with an increase in magnetite and sapphirine and decrease in cordierite toward the upper levels of the quarry. Quartz veins produce garnet reaction rims only in the upper levels where spinel is found. This mineralogical zoning indicates a decrease of magnesium, iron and aluminum oxides and increase in silica with increasing distance from the norite.

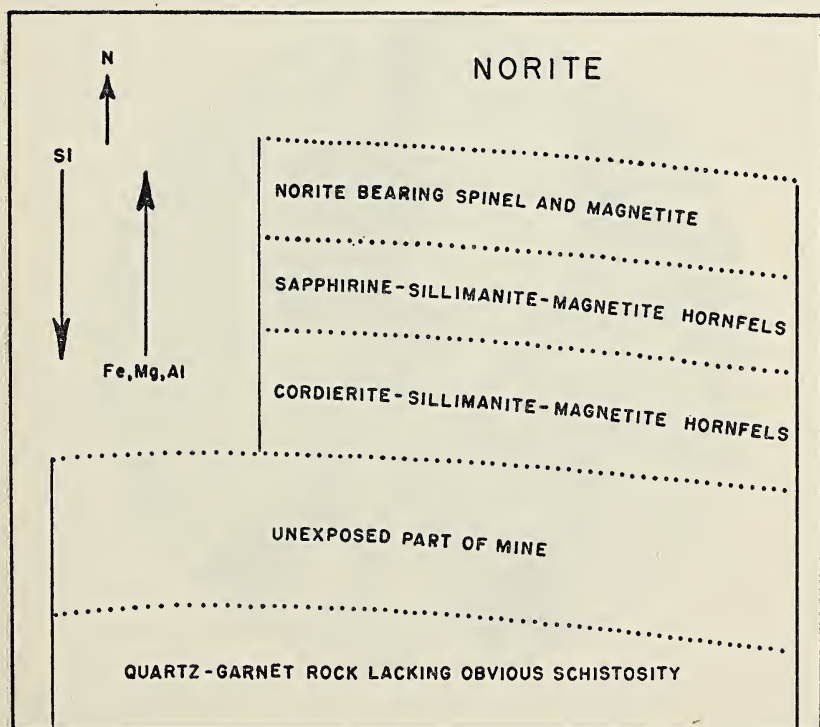


FIGURE 11. Generalized diagram showing zoning in Kingston Mine. The arrows indicate direction of increasing silica and decreasing iron-magnesium-aluminum content.

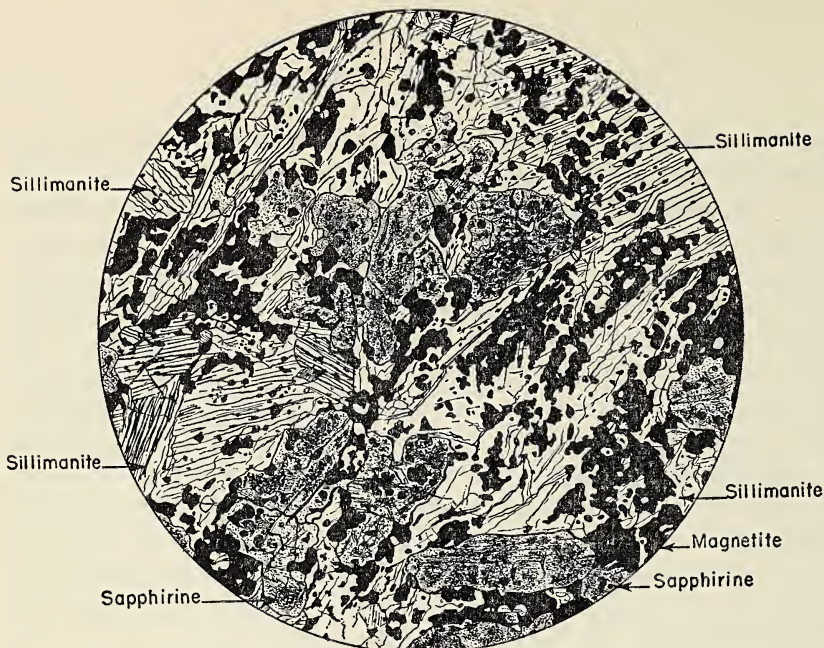


FIGURE 12. Sapphirine-sillimanite-magnetite hornfels. Note the relative abundance and the euhedral character of the sapphirine crystals. Plane light. 51.2 X.

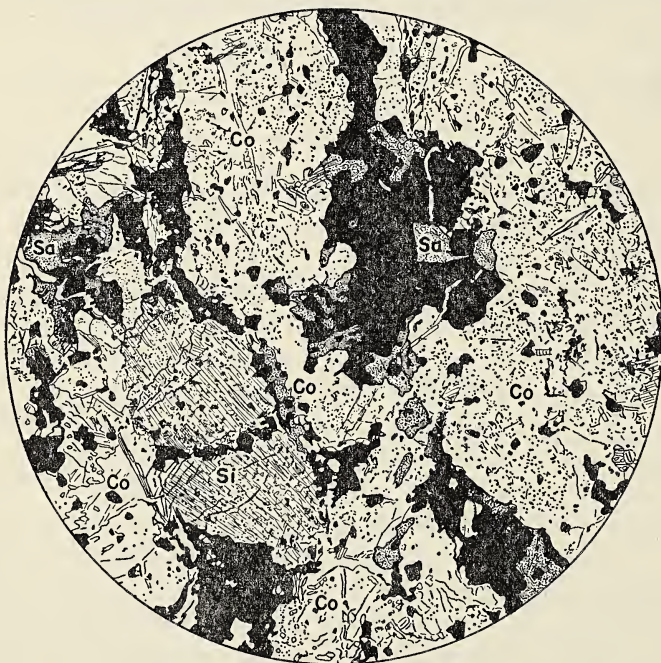


FIGURE 13. Cordierite-sillimanite-magnetite hornfels. Cordierite (Co) is the most prominent mineral and encloses abundant sillimanite needles; prismatic sillimanite (Si) and magnetite (opaque) are less abundant. Sapphirine (Sa; stippled) is relatively uncommon and always anhedral. Plane light. 27 X.

About 150 to 250 feet south of the deepest part of the Kingston Mine a quartz-garnet rock is exposed. This may be the garnet rock cited by Rogers (1911, p. 52). It has a sutured texture and consists of quartz and garnet in the proportions of about 70 percent to 30 percent with accessory biotite and magnetite. The quartz contains numerous inclusions of slender sillimanite needles.

FURNACE DOCK ROAD DEPOSITS

Location. The deposits are located on the east of Furnace Dock Road, north of its intersection with Maple Avenue and about 1 mile southeast of Emery Hill. Emery is exposed on the east side of the road and can be traced through the woods for about $\frac{1}{3}$ mile. Six or seven pits and prospects have been dug. On the hill about 450 feet northeast of the outcrop in Furnace Dock Road emery was once abundantly exposed and extensive mining operations were carried on.

Petrography. The emery consists of corundum, spinel and magnetite; corundum is fairly abundant. The wallrock is norite with poikilitic biotite; poikilitic hornblende is common. Near emery the norite is garnetiferous; the garnets are mostly euhedral. Some are 2 cm. or more in diameter, others a fraction of a millimeter. Biotite is also common, and Rogers (1911, p. 76), who studied the emery when the Furnace Dock Road deposits were still being mined or operations had only shortly ceased, noted the association of emery with what he termed a very biotitic rock.

The wallrock is locally highly feldspathic; pyroxenes are uncommon. Corroded feldspar crystals are enclosed in garnets. Spinel, iron oxides and corundum are molded on plagioclase and occur as inclusions in the latter. From there they ramify through the host crystal and transgress into adjacent feldspars. This points to the replacement of the feldspars by the oxides. Poikilitic biotite is associated with garnets and oxides and encloses corroded plagioclase crystals. The gradational steps in the replacement of plagioclase by biotite can be traced. Hoegbomite occurs as a replacement product of spinel but only in minor amounts. Gillson and Kania (1930, p. 522) state that hoegbomite is of common occurrence in the Cortlandt emery, as it is in the Virginia deposits. Examination of both localities, however, has shown its abundance in Virginia, its comparative rarity at Cortlandt. Criteria for the recognition of hoegbomite have been presented elsewhere (Friedman 1952*b*).

Samples from the most southern exposure show corundum, including sapphire, and some minor spinel associated with garnet, feldspar

and abundant hornblende. The crystals of green hornblende were blotched with blue, and alteration to the blue or more sodic variety had taken place. Sapphire has been reported by Rogers (1911, p. 68) but Gillson and Kania (1930, p. 518) suggest that Rogers misidentified sapphirine. Rogers' description of the mineral makes it apparent that he had mistaken sapphirine; in this study sapphire has been identified for the first time in the Cortlandt rocks.

Quartz veins cutting black emery gave rise to sapphirine, sillimanite, cordierite, andalusite and garnet.

At the north end, black emery is adjoined by gray emery and the following minerals were identified in the latter: sillimanite, cordierite, kyanite, staurolite, garnet, magnetite, hornblende, biotite, plagioclase. Of these, sillimanite, kyanite, magnetite and garnet were the most abundant.

EMERY HILL DEPOSITS

Location. Emery Hill, where the most significant commercial deposits are located, is about $2\frac{1}{2}$ miles east of the town of Peekskill. The area is reached from that town by following Crompond Road which passes directly north of the emery locality. The entrance to the De Luca Mine is on Croton Avenue about $\frac{1}{2}$ mile south of Crompond Road.

Petrography. The only previous systematic emery studies in Cortlandt Township were undertaken at Emery Hill. Since that time the De Luca Mine has been opened for mining gray emery, which previously was not extracted. This presented a new opportunity for studying the genetic relationships.

The black emery is identical with that found elsewhere in Cortlandt Township. The country rock likewise is norite. Thin veins passing through norite and emery were considered cooling-shrinkage fractures by Butler (1936, p. 556) "which have been healed by a flood of deuteric emanations passing off from the yet-liquid magma." Veins in norite are composed of plagioclase which ranges from sodic labradorite to oligoclase, while those in emery are made up of chlorite. The veins may cross from norite into emery.

At the north end of the mine a biotite-garnet rock forms a mantle around black emery. Microscopic examination shows crystals of corundum, spinel and magnetite embedded in mica.

About 30 to 50 feet south of the main gray emery quarry is an abandoned black emery pit. The divide between the two is made up of norite which has undergone hornblendization and replacement by biotite. The norite is traversed by stringers of black emery which con-

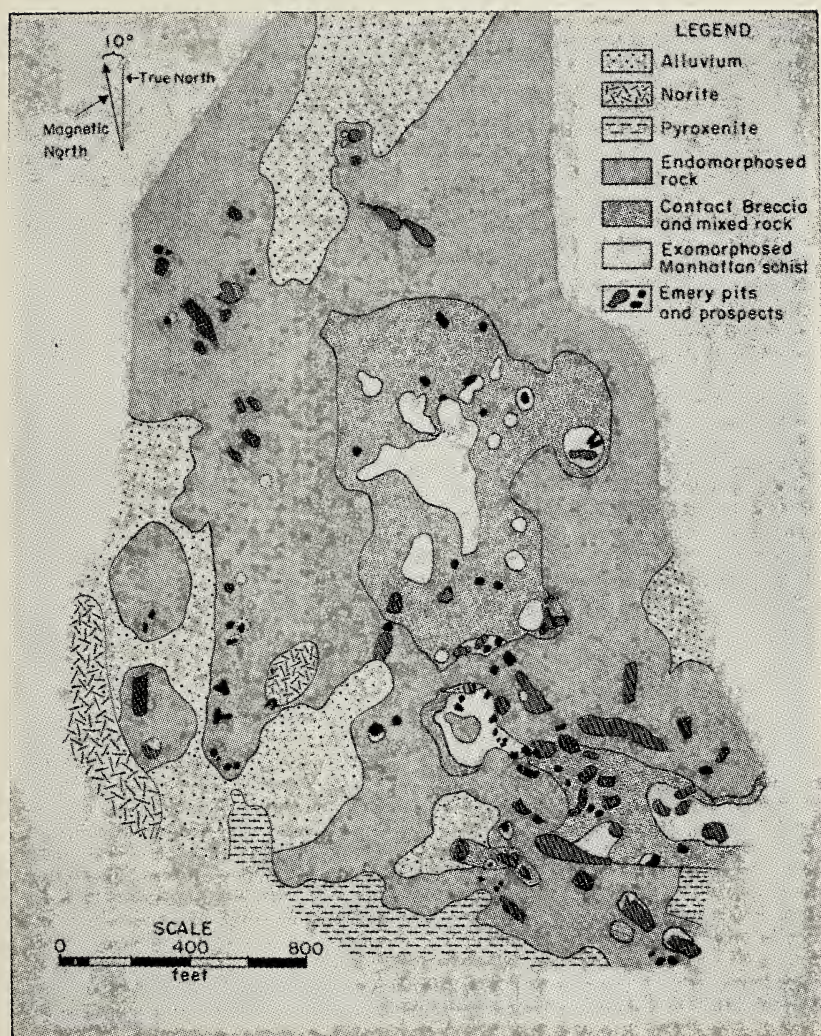


FIGURE 14. Geological map of part of Emery Hill (after J. W. Butler, Jr.)

tain corroded feldspar crystals; these in turn contain small inclusions of emery minerals. Emery grades into norite where corundum, spinel and magnetite corrode the silicates.

Small aplite dikes traverse the norite. The aplite is composed of about 85 or 90 percent quartz and feldspar with varying relative proportions of the two minerals and about 10 percent biotite. The feldspar is chiefly a sodic plagioclase, although some orthoclase was noted. Magnetite and apatite are accessories and tourmaline is locally common. These granite-aplites are more likely to be related to the granite intrusion than to the Cortlandt norite as Butler (1936, pp. 563, 574) assumed.

Gray emery quarried at the De Luca Mine is a cordierite-sillimanite rock with variable amounts of magnetite, sapphirine and andalusite. It has schistose structure, especially where sillimanite is prevalent. Even magnetite, sapphirine and andalusite show parallel alignment, and cordierite occurs as elongated lenses. Sapphirine, which is normally tabular, has increased along *c* and shortened along *b*. Thus some crystals measure $2\frac{1}{2}$ mm. along *c*, only about $\frac{1}{4}$ mm. along *b*. A chemical analysis of the gray emery is given in Table 2.

TABLE 2
Chemical analysis of gray emery
(cordierite-sillimanite hornfels) quarried at the
De Luca Mine, Emery Hill

	<i>Percent</i>
SiO ₂	24.60
Al ₂ O ₃	41.10
Fe ₃ O ₄	25.36
MgO	3.12
CaO	2.55
H ₂ O	0.15
TiO ₂	2.22
TOTAL	99.10
ANALYST	N. J. Federici

The norite on the north side of De Luca's main quarry is cut by quartz and calcite veins with which chlorite, tourmaline and biotite are associated. The border of the norite with the gray emery is marked by garnets, some of which are 3 or 4 inches in diameter. Locally these are so abundant that the rock takes on a red color. Garnets enclose corundum, spinel, magnetite, sapphirine and a little sillimanite. The garnet rock is followed to the north by norite in which spinel, corundum and magnetite corrode feldspar and to the south by gray emery which is mainly composed of sillimanite and also contains staurolite, sapphirine, magnetite, a little biotite and hornblende.

The wallrock on the north side of the quarry consists locally of biotite with abundant allanite, magnetite, sillimanite and occasional sapphirine and pyrite crystals. Allanite as well as tourmaline and possibly quartz are said by Butler (1936, p. 547) to have been introduced from the Cortlandt magma. The Peekskill granite seems a more likely source.

CONTACT METAMORPHISM AT THE CORTLANDT COMPLEX

A zoning effect is recognized in thermal metamorphism, just as in regional metamorphism, depending on the rock types involved in the metamorphic changes and on the highest temperatures attained in the various zones; but as Harker (1932, p. 20) points out "with the proviso that the high temperature was maintained long enough for the possibly slow process of metamorphism to be completed." Besides temperature, introduction of new constituents from the magma plays a dominant role. This was shown by Williams at Cortlandt as early as 1888.

The metamorphic aureole only extends a small distance from the contact, at the most about 200 or 300 feet. The Inwood limestone is bleached and locally more coarsely crystalline and lime-rich amphiboles and pyroxenes have been developed, an observation first made by Williams (1888, p. 267). The Cortlandt Complex, however, only adjoins the limestone in a very small area at the south end of the intrusive, and no conspicuous zoning can be recognized in that area. However, in the Manhattan schist metamorphic differentiation can be demonstrated on the basis of both mineralogical and chemical studies. The metamorphic zones in a contact aureole of a given intrusive are broadly similar to those where comparable geological conditions exist, yet because of slight differences in the composition of the country rocks or igneous bodies, and differences in the temperature and pressure conditions at the time of metasomatism, they differ in detail. From the point of view of detail the contact aureole of the Cortlandt Complex is unique. Gillson and Kania (1930) and Butler (1936) stressed the metamorphism in the formation of the emery deposits, but did not recognize the zoning in the contact aureole. The rocks of the inner aureole at Cortlandt can best be referred to the pyroxene-hornfels facies of Turner & Verhoogen (1951) and those of the outer aureole to the amphibolite facies.

The metamorphic zones of Becke, Grubenmann and Niggli (Read, 1948) will serve as a guide in clarifying the progressive zones at Cortlandt. Although these investigators are primarily concerned with depth zones, their mineral suites are similar to those found in many

contact metamorphic aureoles. Furthermore, many modern metamorphic petrographers, such as Billings (1937) in his New Hampshire investigation, consider in regional metamorphism "rising temperatures to have been the dominant factor in causing a progressive increase in the intensity of metamorphism" (Billings, p. 539). As far back as 1893 Barrow (p. 337) came to a similar conclusion. The index minerals of the high temperature or katazone of Becke, Grubenmann and Niggli are, among others, feldspars, sillimanite, cordierite, spinel and garnet. Harker (1932, p. 62) cites corundum among the high temperature derivatives of aluminous and ferruginous rocks in thermal aureoles. The mesozone is indicative of somewhat lower metamorphic temperatures (pressures are not considered here) and includes kyanite, staurolite, almandine garnet, micas and hornblende as characteristic minerals.

The minerals of the epizone (moderate temperature) need not be considered, as at Cortlandt thermal metamorphism is superimposed on a mica-schist. Barth (Balk and Barth, 1936) has shown that in Dutchess County, New York, the highest metamorphic zone is made up of sillimanite-gneiss and is in turn followed by a kyanite-schist zone characterized by garnet, kyanite and staurolite. The distribution of the zones appears to have no depth significance and is related to the degree of metasomatism. At Cortlandt metasomatism is likewise responsible for the distribution of the zones.

Williams (1888) made three traverses across the Manhattan schist-diorite contact at the southwestern boundary of the Cortlandt Complex near Crugers. He (pp. 255-256) notes that "the intensity of the metamorphic changes is directly proportional to the nearness of the schist to the massive rocks" (diorite). In the schists staurolite, sillimanite, kyanite and garnet are developed near the intrusive, and the metamorphism "consists of an addition of alumina and iron and the corresponding decrease in the proportions of silica and the alkalies" (p. 259). Williams (p. 259) cites four chemical analyses in support of these conclusions.

A short consideration of the spinel-silica reaction succession, presented in detail elsewhere (Friedman, 1954), will clarify some of the metamorphic changes about to be described. In the equilibrium diagram (Figure 15), spinel and quartz, the end members of the reaction succession, are separated from one another by a quadrilateral field having at its apices garnet, sapphirine, sillimanite and cordierite. These are intermediate products formed in the reaction between the spinel of emery and transgressive quartz veins as illustrated in equations 1, 2 and 3 (p. 18). Addition of a relatively small amount of silica to the spinel will give rise to sapphirine; it requires more silica to form

15 percent. The sapphirine occurs in euhedral crystals. The next zone is formed by a cordierite-sillimanite-magnetite hornfels with small amounts of sapphirine, mica and accessory minerals. Estimated percentages are cordierite 50 percent, sillimanite 25 percent, magnetite 15 percent, sapphirine 9 percent, mica $\frac{3}{4}$ percent, spinel, corundum, hoegbomite and zircon total $\frac{1}{4}$ percent. Locally some plagioclase, labradorite of composition An_{59} , has been noted. This mineral combination as well as the textural relations of the minerals are of interest. In hornfels containing abundant cordierite, the sapphirine is anhedral and shows signs of corrosion. If spinel is present, it occurs as relics enclosed in sapphirine or magnetite. Sapphirine and spinel are unstable in cordierite association. At a somewhat greater distance from the norite sapphirine disappears. The few corundum grains noted were enclosed in magnetite and showed signs of corrosion.

Of interest is the complete absence of garnet as an important constituent of a zone intermediate between the sillimanite-sapphirine-magnetite hornfels and the cordierite-sillimanite-magnetite hornfels. This is expected, as garnet is formed at temperatures below that at which cordierite or sapphirine are formed. Garnet is an essential constituent of a zone found at a somewhat greater distance from the intrusive contact. A correlation between the zones of the metamorphic aureole and the zones bordering transgressive quartz veins in emery is possible, but in the one case, silica has been added to spinel, while in the other magnesium and iron ions have been added to the silica; the resultant reaction products are the same.

The metamorphic zones at the Kingston Mine have just been listed, except for the most southern outcrops at that locality. The latter are quartz-garnet rocks, in which the quartz predominates and encloses minute sillimanite needles. The metamorphic zones described above were observed over a total distance of 60 to 80 feet in the main working of the Kingston Mine. The intervening distance of about 80 feet between the most southern exposure of the cordierite-sillimanite hornfels and the quartz-garnet rock is devoid of exposures.

It seems likely that quarrying operations in that area would uncover further zones. To find additional zones the metamorphic petrographer has to follow in the stratigrapher's footsteps. If a succession of facies cannot be traced across the strike in one limited area, correlation must be made by observations in several distinct and separate localities.

In the De Luca Mine at Emery Hill sapphirine-sillimanite-magnetite and cordierite-sillimanite-magnetite zones were also noted. In drill-cores, rocks were obtained containing a mineral assemblage indicative of lower temperatures as follows, the minerals being listed in order of decreasing abundance: sillimanite, kyanite, staurolite and garnet (almandine?) with small amounts of magnetite, cordierite, mica and chlorite. A similar suite of minerals from the Furnace Dock Road deposits shows the following in decreasing abundance: kyanite (by far the most prominent), cordierite, garnet, staurolite, magnetite, sodic hornblende, biotite, plagioclase, sillimanite (uncommon). Although no decreasing distance from the norite can be proven, these mineral suites are indicative of lower temperature conditions than the cordierite-sillimanite zone and may therefore be considered a separate zone.

Summarizing, the following zones are apparent: 1, a sillimanite-sapphirine zone; 2, a cordierite-sillimanite zone; 3, a kyanite-staurolite-garnet (almandine?) zone in which cordierite and/or sillimanite may also be prominent; 4, a quartz-garnet zone in which the quartz encloses minute sillimanite needles. Some authors regard spinel and corundum as characteristic of the zone of most intense metamorphism. Although these minerals form replacement products of the norite, they may be included in this list and considered as forming an additional zone.

Miyashiro (1953, p. 192) states that in thermal-metamorphic rocks "pyrope never occurs, and almandine does not occur ordinarily." He adds that "when certain almandine-bearing mica schists were thermally metamorphosed, the almandine was observed to be replaced by pseudomorphs of cordierite and magnetite. These facts suggest that pyrope and almandine are not stable in ordinary thermal metamorphism. On the other hand, Mn-rich pyralspites occur not infrequently in hornfelses. Tilley (1926) has laid stress upon the presence of MnO as promoting the formation of pyralspite in contact zones of pelites."

Rogers (1911) reports 0.19 percent MnO in his composite analysis of five Manhattan schist specimens and 0.25 percent MnO in the sillimanite hornfels. The garnet of the Cortlandt hornfels has not been analyzed for MnO but that bordering quartz veins in emery carries 0.75 percent MnO, and it is reasonable to believe that the garnet of the hornfels is not unusually rich in this constituent. Miyashiro considers a hornfels of this type as "extraordinary." According to his classification, the Cortlandt hornfels has formed by "intermediate or fairly almandinous, static metamorphism."

The zones of the metamorphic aureole can also be established from a study of chemical analyses. Table 3 gives one analysis of emery (spinel-corundum zone), one of a sapphirine-sillimanite hornfels, two

Chemical analyses of emery, hornfels and unaltered mica-schist

THE ORIGIN OF SPINEL-EMERY DEPOSITS

37

	1		2		3		4		5		6	
	SPINEL EMERY		SAPPHIRINE SILLIMANITE		CORDIERITE- SILLIMANITE		CORDIERITE- SILLIMANITE		KYANITE-GARNET- STAUROLITE*		MICA- SCHIST	
	Percent		Percent		Percent		Percent		Percent		Percent	
SiO ₂	1.93*		16.35		27.35		33.35		40.16		62.980	
Al ₂ O ₃	68.14		53.12		49.48		42.53		29.50		16.881	
Fe ₂ O ₃	1.43	17.68	21.16		19.97		17.22		19.66	25.46	2.479	7.479%
FeO	16.25								5.80		5.000	
MgO	10.02		3.85		2.98		4.07		0.85		1.580	
CaO	trace		4.63		not present		2.10		trace		trace	
Na ₂ O	trace		—		—		—		1.46		3.020	
K ₂ O	trace		—		—		—		1.36		7.450	
H ₂ O ⁺	1.15				—		—		—		—	
H ₂ O ⁻	0.12		0.46		—		—		—		—	
TiO ₂	1.41		—		—		—		—		—	
P ₂ O ₅	trace		—		—		—		trace		trace	
S	0.05		—		—		—		0.82		0.080	
Cr ₂ O ₃	0.04		—		—		—		—		—	
MnO	trace		—		—		—		—		—	
TOTAL	100.54		99.57		99.78		99.27		99.61		99.470	
Analyst	G. S. Rogers	F. Konstandt	E. A. Haller	E. A. Haller	F. L. Nason	F. L. Nason	F. L. Nason	F. L. Nason	F. L. Nason	F. L. Nason	F. L. Nason	F. L. Nason

* Staurolite and cordierite were not reported in the rock analyzed. Magnetite and biotite were noted. Williams, 1888, p. 259

Remarks * probably derived in considerable part from the agate mortar
Reference G. S. Rogers, 1911, p. 64
Williams, 1888, p. 259

of cordierite-sillimanite hornfels, one of kyanite-garnet-staurolite hornfels¹ in which sillimanite and/or cordierite may be prominent, and one of unaltered mica-schist. The significant changes are represented by a decrease in silica and an increase in aluminum with decreasing distance from the norite, and to a lesser extent by an increase in magnesium and ferrous iron and a decrease in alkalis. Reference to Table 4 also suggests a small increase in TiO_2 . This is supported by the observation that spinel relics in the cordierite-sillimanite zone have been locally replaced by hoegbomite.

Sixteen chemical analyses of rocks from the various zones of the metamorphic aureole and of unaltered mica-schist have been plotted in a composition triangle (Figure 16) which has as corners SiO_2 , Al_2O_3 and $(\text{Mg},\text{Fe})\text{O}$. The corresponding index minerals of the various zones have been placed on the diagram next to the analyses.

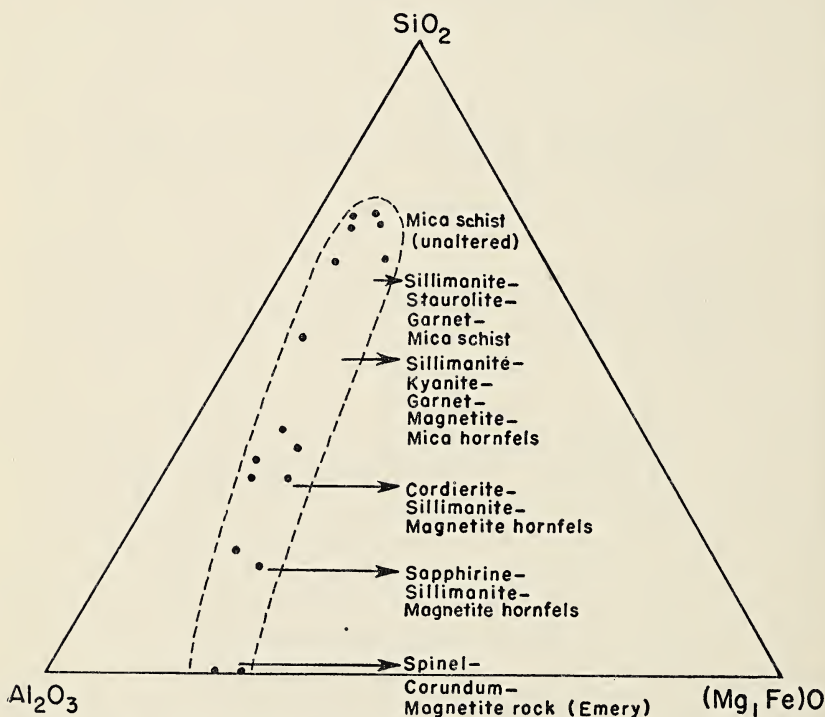


FIGURE 16. Composition triangle with Al_2O_3 , $(\text{Mg}, \text{Fe})\text{O}$ and SiO_2 as corners. Dots represent chemical analyses of rocks from various zones of the metamorphic aureole and of unaltered mica schist and emery. The corresponding index minerals of the various zones have been placed next to the analyses. Each zone has its characteristic mineralogical and chemical composition. The diagram indicates an increase in Al_2O_3 and $(\text{Mg}, \text{Fe})\text{O}$ and a decrease in SiO_2 toward the norite.

¹ Staurolite and cordierite were not reported in the rock analyzed.

TABLE 4

TiO₂ content of emery, hornfels and mica-schist

PURE EMERY	SPINEL EMERY	SILLIMANITE SCHIST (HORNFELS)	CORDIERITE- SILLIMANITE HORNFELS	MICA-SCHIST (UNALTERED)
(Analyst) G. S. Rogers 3.28%	G. S. Rogers 1.41%	G. S. Rogers 2.76%	N. J. Federici 2.22%	G. S. Rogers 1.01%
(Reference) Rogers p. 64	Rogers p. 64	Rogers p. 65	New analysis	Rogers p. 65

From an examination of this diagram it is apparent that each zone has its characteristic mineralogical and chemical composition. It also stresses the fact that the formation of a given metamorphic zone in the Cortlandt aureole not only depended on the prevailing physical conditions, such as temperature, but also on the amount of aluminum, magnesium and iron ions that have been introduced by the Cortlandt intrusive.

THE VIRGINIA EMERY DEPOSITS

LOCATION

The deposits are located in the north-central part of Pittsylvania County, about 2 miles west of Whittles and 20 miles north of Danville.

GENERAL GEOLOGY

The area in which the emery deposits are located is part of the crystalline complex of the Piedmont. A variety of deeply weathered igneous and metamorphic rocks encloses the deposits. Of these a garnetiferous mica schist, the so-called Wissahickon schist, is the most abundant. It is regarded as Precambrian or early Paleozoic.

The schist has been intruded in the late Precambrian or early Paleozoic by basic and ultrabasic rocks. Only one such body was observed in the field; but for the deep weathering, others might have been found. Basic rocks are very widespread in the Piedmont, particularly as intrusives in Wissahickon schist. In his study of emery deposits, Watson (1923) overlooked the basic rocks.

The garnetiferous schist was injected later by lenticular bodies of the Leatherwood granite of late Paleozoic age. Aplites, pegmatites and quartz veins, related to the granite, cut schist and basic rocks.

The emery deposits are considered replacements of basic rock; they occur in irregularly shaped or lenticular bodies.

PETROGRAPHY

The Wissahickon schist consists mainly of biotite and quartz with muscovite, sillimanite and magnetite as minor constituents. Sillimanite is rare or absent in samples taken at some distance from emery deposits. However, it is abundant near the deposits, where the schist also contains much magnetite which is rare at some distance from the emery.

Because of subsidence of the original pits and surface weathering it was not possible to obtain schist samples very close to emery deposits. Watson (1923, p. 59), who studied the emery when mining operations were still carried on, noted that schist close to the deposits assumed a gray color. He identified the following minerals: sillimanite, cordierite, andalusite, biotite, magnetite and spinel. The mineral composition and color of this modified schist is therefore similar to that of the gray emery of Cortlandt Township, New York.

Watson (1923) cited the following analyses of mica schist and what he termed altered schist (cordierite-sillimanite rock or gray emery).

TABLE 5

Analyses of fresh and altered schists, Pittsylvania County,
Virginia, emery area

	Percent Footnote 1	Percent Footnote 2
SiO ₂	51.76	31.96
Al ₂ O ₃	25.71	43.46
Fe ₂ O ₃	1.66	7.08
FeO	7.73	9.07
MgO	2.21	4.62
CaO	1.32	.06
Na ₂ O	.91	—
K ₂ O	5.73	.37
H ₂ O—	.25	.21
H ₂ O+	1.18	1.24
TiO ₂	1.15	1.78
MnO	.04	.11
BaO	.51	—
P ₂ O ₅	.11	.08
	100.27	100.04

1. Fresh mica schist, Bennett barite mine near Toshes, Pittsylvania Co., Virginia. (Penniman & Browne, analysts). Watson, 1923, p. 58.

2. Altered schist or gray emery near emery openings on Yeatts place, 1½ miles northwest of Whittles, Pittsylvania Co., Virginia (S. D. Gooch, analyst). Watson, 1923, p. 58.

The altered schist or gray emery has a lower silica, but higher iron, aluminum and magnesium content than fresh schist. The latter was

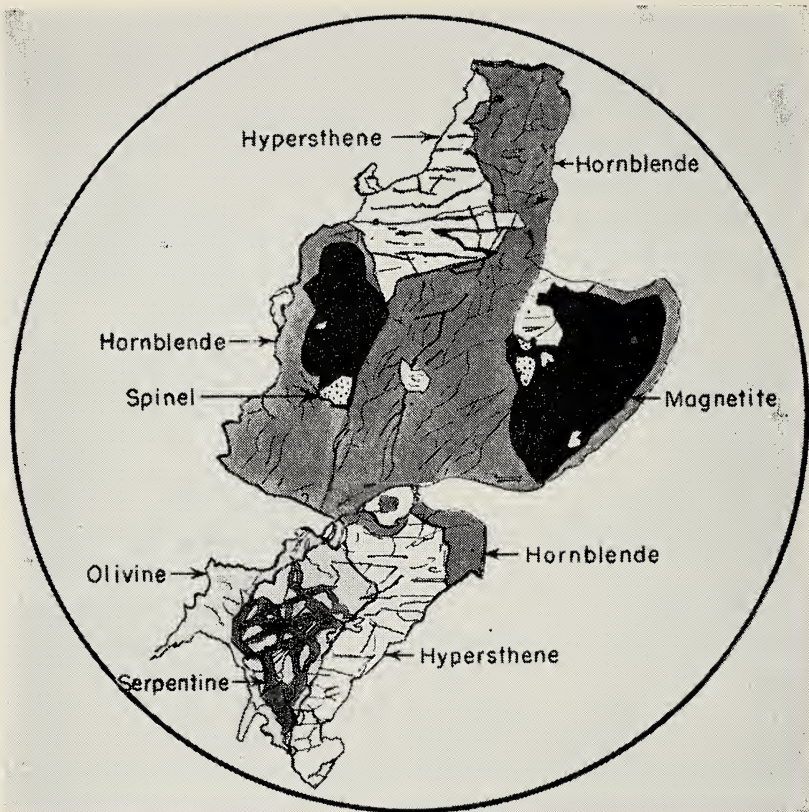


FIGURE 17. Gabbro, Pittsylvania County, Virginia, emery area. Hornblende, spinel and magnetite have replaced hypersthene and locally enclose corroded hypersthene grains. The white area represents feldspar. Although hypersthene is prominent in this drawing it is not sufficiently common to warrant use of the term norite. Plane light. 105.6 X.

sampled about 6 miles northwest of the deposits. It is devoid of magnetite, cordierite and sillimanite. Closer to the deposits the schist contains a greater amount of minerals bearing iron, magnesium and aluminum. Analyses prepared from samples taken at varying distances from the emery deposits probably show a gradational increase in iron, aluminum and magnesium and a gradational decrease in silica. Definite zones could not be established in the field.

Thin sections of the gabbro show the principal minerals to be diallage and labradorite with variable amounts of olivine, hypersthene and hornblende. Biotite, muscovite, titaniferous magnetite and spinel are accessory. Brown hornblende is a replacement product of both pyroxenes. It replaced the pyroxenes particularly along their margins. Occasionally replacement went almost to completion and corroded pyroxene relics are enclosed in hornblende. Spinel and magnetite crystals may be associated with hornblende and corroded hypersthene. The spinel is green and probably of the same composition as that in emery. Feldspar crystals show dense but patchy cloudiness caused by a concentration of minute specks. The paragenesis of the rock is olivine, pyroxene, feldspar, hornblende with magnetite and spinel.

In many thin sections of the emery, spinel is the dominant mineral, corundum is lacking or is only a minor constituent. A chemical analysis of the spinel is given in Table 6.

TABLE 6
Chemical analysis of spinel
(Watson, 1925, p. 8)

	<i>Percent</i>
SiO ₂	0.92
TiO ₂	0.67
AlO ₃	53.52
Fe ₂ O ₃	10.35
FeO	24.53
MgO	10.02
TOTAL	100.01
ANALYST George Steiger	

Magnetite is the second most important mineral quantitatively. Many prismatic corundum crystals are entirely surrounded by magnetite, but magnetite also occurs as inclusions in both corundum and spinel.

Hoegbomite is found in many samples where spinel is abundant. It seems to have formed at the expense of the earlier spinel. Spinel crystals are mantled with hoegbomite and occasionally enclose hoegbomite replacement nuclei. Spinel crystals enclosed in corundum were not replaced.

Marginally the emery usually contains abundant chlorite. In some

samples chlorite makes up almost 50 percent. Magnetite and corundum crystals are interspersed between the chlorite flakes.

Pleochroic staurolite also occurs in marginal emery rich in chlorite. Staurolite is euhedral, prismatic. Thin sections containing staurolite are devoid of spinel, low in corundum, high in chlorite and of variable iron oxide content.

THE NORTH CAROLINA EMERY DEPOSITS

LOCATION

Most deposits are located on Fairview Ridge about 4 miles southwest of Franklin. They can be reached from Franklin by following U.S. 23 south for about 5 miles, then turning west before crossing Skeenah Creek. A northward road leads to the top of Fairview Ridge. The old emery mines are about 1 mile north of the junction of the two roads. Other abandoned mines are on Dobson Mountain, which adjoins Fairview Ridge due west of the latter, and in the Little Tennessee River valley west of U.S. 23. An index map has been given elsewhere (Friedman, 1952b).

GENERAL GEOLOGY

The geology is very similar to much of the rest of western North Carolina; the area is underlain by the Carolina and Roan gneisses which are probably Precambrian. These gneisses are heterogeneous metamorphics; the former is composed of dominantly acidic, the latter of dominantly basic metamorphic types.

The Carolina gneiss is a mica schist and mica-garnet schist in the immediate vicinity of the emery deposits, while the Roan gneiss is of dioritic composition.

The rocks have been intruded in the Precambrian or early Paleozoic by ultrabasics, chiefly dunites and peridotites, many of which were altered to talc and soapstones. The younger Franklin-Sylva belt of granite pegmatites, a northeast trending belt 14 miles wide and 45 miles long, intruded the ancient schists and gneisses of the Dobson Mountain-Fairview Ridge area. Mica mines encircle this area.

The main rock exposed on Fairview Ridge is a saprolite. It is therefore impossible to classify the highly altered rock associated with the emery. However, on the northern slope of Fairview Ridge, Roan gneiss outcrops. Similarly, emery deposits in the Little Tennessee River valley are associated with Roan gneiss, as are emery deposits on Dobson Mountain. The latter are also associated with talc. As the emery is spinel-bearing and as spinel-emery elsewhere occurs in a pyroxenic basic rock, this is perhaps the same here. Basic and ultrabasic rocks affected by hydrothermal emanations from acid intrusives give rise to talc. As talc adjoins the Dobson Mountain deposit and as

peridotites are common in this area, it is believed that the rock replaced is of this type. The emery seems to occur in irregular lenticular bodies. No evidence of zoning, such as described from the Cortlandt deposits, has been noted in this area.

PETROGRAPHY

The Carolina gneiss is medium to coarse-grained and composed essentially of alternating layers of quartz and mica. Thin sections show quartz, biotite, garnet, chlorite and sericite as principal minerals. Plagioclase, zircon and magnetite are accessory constituents. Kyanite blades, 2 inches long, were found as float on the gneiss.

The Roan gneiss is a medium-grained rock of mottled appearance. Thin sections show andesine, An_{36} , and biotite as main constituents, with variable amounts of garnet and epidote. Apatite, chlorite and magnetite are accessory minerals.

The emery is a black, heavy, magnetic aggregate, but specimens with much staurolite and chlorite are generally gray and not very magnetic. The grain size of the minerals is highly variable, many corundum crystals exceed 2 mm. in diameter; spinel, hoegbomite and magnetite usually have smaller dimensions.

The emery consists chiefly of corundum, spinel, titaniferous magnetite and hoegbomite. The refractive index of the spinel is 1.778 which is between that for pleonaste and hercynite.¹

Corundum forms anhedral crystals, but many are prismatic. A few crystals show rhombohedral partings, and many contain inclusions of magnetite, spinel and hoegbomite.

The rich green, isotropic spinel may show partings; a few crystals exhibit irregular fractures. Many crystals are mantled with hoegbomite and also enclose small grains of this mineral; apparently hoegbomite formed at the expense of earlier spinel. In some thin sections only relic centers of spinel in hoegbomite remain. Two varieties of hoegbomite were discovered and have been described (Friedman 1952b). Subhedral to anhedral magnetite crystals are abundant and prismatic corundum may be entirely surrounded by magnetite. Magnetite may also occur as inclusions in corundum, spinel and hoegbomite.

Chlorite is common in some thin sections and pleochroic from green to colorless. It is biaxial positive, $2V$ variable from nearly 0° to 10° . The birefringence is low, α and β are near 1.591, and $\gamma = 1.600$.¹

Pleochroic staurolite is abundant in one of the sections of emery from a prospect in the Little Tennessee River valley. Staurolite is euhedral, prismatic; the grain size varies up to 3×0.2 mm.

¹ Determined by Miss Jewel J. Glass of the U. S. Geological Survey.

FOREIGN EMERY DEPOSITS

Foreign emery deposits of importance occur in the Urals, Siberia and Turkestan, the Cyclades Islands and Asia Minor. Others have been reported from Brudenell Township, Ontario, Canada (Eardley-Wilmot, 1927, p. 37); from the Salem district of India (Indian Geological Survey, Bull. 43, undated); from Nundle, New South Wales (Trickett, 1919); Crookwell, N. S. W. (Imperial Institute, 1929); Southport, southeast of Brisbane, Queensland (Queensland Geol. Surv., 1913); West Kimberly, West Australia (Simpson, 1919); Deschnet, Iran (Ladoo, 1949); Cerro Redondo near Minas, Uruguay (Marstrander, 1916); San Francisco Valley, Uruguay (Miller and Singewald, 1919); Wildenreuth, Germany (Barlow, 1915); Frankenstein near Darmstadt, Germany (Klemm, 1907); Laudenau and Klein-Gumpen near Reichelsheim, Germany (Klemm, 1916); and Ochsenkopf near Schwarzenberg, Germany (Bergeat, 1904). Other minor deposits undoubtedly occur elsewhere. Though worldwide in extent, the deposits are of relatively rare occurrence.

Several small emery bodies have been studied by Klemm (1916). The deposits of Laudenau and Klein-Gumpen occur in the region of probably Precambrian crystallines, which have been intruded by basic and subsequently acid igneous rocks. They are found in the contact zone of diorites and gabbros with granites. Aplites and pegmatites of granite cut both basic and acid rock. At Nieder-Beerbach, about 6 miles to the northwest, a number of deposits occur in gabbros, serpentines and amphibolites between $\frac{1}{4}$ and 1 mile away from the granite contact.

At Wildenreuth in Bavaria there are commercial deposits, but these have not been described. The geological map of Bavaria (Sheet 8, Erbendorf) shows Wildenreuth to be near the contact of diorite with an acid igneous body; eclogites, rocks typical of acid intrusions into basic rock (Hentschel 1937), are represented on the map.

Emery deposits of the Irtash region (Ozerov, 1933) occur near Kyshtym in the Russian Federated Socialist Republic. The Irtash complex consists of chloritoid schists, marbles, serpentines, amphibolites and granites. The Irtash deposits occur in marble near serpentine, the Tehen and Kysyl-Tash deposits about 2 miles from serpentine in limestone adjoining granite gneiss and amphibolite. Large granite bodies occur to the west and southwest. Pegmatites are abundant. Ultrabasic rocks west of the emery reacted with granitic magma to form corundum-bearing plagioclase-rich rocks, the so-called kyshtymites.

Commercial emery deposits are abundant in the Precambrian crystallines of the Balkans and Asia Minor. In the Greek Archipelago, the island of Naxos is the most important locality. According to

Papavasiliou (1914), emery occurs in a limestone associated with amphibolites. Granite injections are abundant and so are tourmaline pegmatites. The island of Iraklia is made up of mica schist and limestone; amphibolite and granite intrusives occur again here. Emery is found in limestone. The geology of the island of Sikinos is the same as that of Iraklia and similarly shows emery-bearing limestone, amphibolite and granite injections. Kyshtymites, such as formed in the Urals as reaction products of granitic magma with serpentines and amphibolites, also occur on Naxos.

The emery deposits of Asia Minor occur in a limestone belt surrounding the Menderes massif. Inliers of limestone in the massif are also emery-bearing. The massif, presumably Precambrian, is made up of gneisses, mica schists and amphibolites and is intruded by granites, diorites, gabbros and peridotites. According to the geological map, a belt of basic rocks surrounds the massif. The map of Phillipson (1913-14) shows basic rocks also in the center of the massif, close to the large emery deposits of the west and similarly of the southeastern part of the Menderes complex. The granite bodies are mainly confined to the center of the massif. In composition the Turkish emery agrees with that of Massachusetts. In all these cases spinel is absent. There has been much divergence of opinion concerning the origin of the emery deposits in Asia Minor. The protagonists of the bauxite theory are still preponderant.

In the Kyzul-Kumy desert of the Kara-Kalpak Autonomous Soviet Republic are deposits considered by Oenay (1949, p. 474) to be analogous to those of Asia Minor. These have been described by Sodedko (1939) as occurring in Silurian limestone intruded by a granite mass. Sodedko maintains that they are metamorphosed bauxites yet admits that bauxites are not known in the limestone. It may be significant that on the map of Turkestan basic rocks feature prominently where emery deposits are located and where granite intrudes the Paleozoic formations.

The deposits of the Upper Veltin (Linck, 1893, p. 47) in northern Italy (Valtellin of the Italian maps) show considerable resemblance to those of the Cortlandt complex. Emery in composition similar to that of Cortlandt occurs in a gabbro containing poikilitic hornblende. Acid igneous rocks of later age are abundant and widespread.

The gabbro of Haddo House in Aberdeenshire, Scotland, and its included emery deposits have been described by Read (1931) and are compared by him with the emery deposits of the Cortlandt complex. The geologic map of the younger plutonic rocks of northeast Scotland

(Read, 1923, p. 447) shows a granite body adjoining and intrusive into the gabbro mass of Haddo House.

Sapphire-spinel rocks occurring in the hypersthene gabbro of the Ardnamurchan Tertiary complex of the west coast of Scotland are associated with intrusive granite masses (Geol. Surv. Scotland, sheet 51, 1927). Similarly on the Island of Mull, west of Scotland, where corundum-spinel-sillimanite rocks occur in tholeiitic sills, intrusive granites are abundant (Geol. Surv. Scotland, sheet 44, 1923).

The corundum-spinel-sillimanite rock in the norite of the Bushveldt complex, South Africa, contains tourmaline and veins of coarse quartz-tourmaline are close by (Hall and Nel, 1926). The effects of acid igneous emanations appear evident.

The major emery localities in Australia are in New South Wales. The pertinent geological map (Trickett, undated) shows a belt of serpentine stretching from south of Warialda, N. S. W., southward and then turning sharply southeast to Port Macquarie, N. S. W., on the Pacific coast. The belt is adjoined in the north by younger granite. Emery occurs at Nundle, where an approximately northwest-trending serpentine body is adjoined on the east by an outlier of the granite intrusive.

ORIGIN

Williams' (1887) theory of magmatic segregation of the Cortlandt emery is only referred to on historical grounds. Following a more complete petrographic study, he proposed (1888) contact metamorphism. Rogers (1911, p. 80), Watson (1923, p. 75) and Butler (1936, p. 568) present objections to the theory of magmatic segregation.

Rogers suggested that the emery formed by the assimilation of schist by basic magma. Rogers' arguments, which overlooked field relationships, were based on experiments of Morozewicz (1898). Gillson and Kania (1930, pp. 526-527) and Butler (pp. 568-569) present evidence against his conclusions. Watson believed that some Virginia deposits are altered schist inclusions in granite. Field examination did not confirm Watson's findings and he admitted (p. 65) that, because of deep weathering, "details of geological relationships . . . are more or less obscured."

Watson held that the emery deposits are developed in schist near the granite-schist contact and are of contact metasomatic replacement origin. Black emery, however, does not appear to have formed in this manner as magnesium, iron and aluminum ions would have reacted with the silica to form cordierite and sillimanite instead of corundum and spinel. This is apparent from the observation that spinel and quartz

are incompatible at the temperatures represented by the emery-hornfels mineral assemblage. Furthermore, field examination showed the emery to be related to a basic rock, not to the schist.

Gillson and Kania proposed that emery was of contact metamorphic, late magmatic origin. They based their theory on seven major premises, summarized as follows:

1. Emery is only associated with modified norite and schist. It is not in contact with unmetamorphosed norite.

2. The minerals have contact metamorphic affinities.

3. The sequence of mineralization is characteristic of contact metamorphic processes.

4. The location of emery bodies far within the wall-rock precludes their formation by magmatic reaction.

5. The feldspar of the emery is andesine, which formed at the expense of labradorite after consolidation. Emery formation followed andesinization.

6. Quartz and corundum were noted in the same thin sections. Magmatic absorption would have given rise to aluminum silicates.

7. Many minerals prove, by their presence, an origin by emanations.

Gillson and Kania were mainly concerned with disproving Rogers' theory. Their observations, except the third and fifth, were confirmed in this study. The paragenesis is too complex to be apparent from boundary relations in a few thin sections from only one area of Cortlandt Township. Cordierite, sillimanite and garnet are said to have formed before spinel, magnetite and corundum; but this is not the case in the black emery, where the last group of minerals preceded the first group. Gillson and Kania did not observe the antipathetic relationship between spinel and quartz. In gray emery, where magnesium, iron and aluminum ions gave rise to cordierite and sillimanite by reaction with the silica of the schist, spinel and corundum relics are unusual; except in a narrow zone close to the norite where a relative dearth of silica permitted their limited crystallization. No observations suggest that andesinization preceded emery formation, a conclusion with which Butler concurs. If quartz is found in the same thin sections as corundum it has been derived from veins.

Gillson and Kania do not present evidence for any reactions that led to emery formation, but merely state on the basis of the observations summarized above that the "emery deposits are contact metamorphic in origin and were formed by gaseous or liquid emanations from the magma reservoir, which passed upward through the already solid

border of the igneous mass and into the schist, depositing the ore minerals in both the endomorphic and exomorphic zones" (1930, p. 526).

Evidence for contact metamorphism is abundant in the area. McGregor (1931) has shown that clouded feldspars indicate metamorphic effects, and these feldspars are common at Cortlandt. Gillson and Kania, however, did not recognize the modifying influence of the nearby granite and its role in emery formation. They did not observe the characteristic replacement of pyroxenes and feldspars by emery minerals, although they noted the association of emery with norite containing abundant poikilitic hornblende and biotite. They (p. 513) referred to this rock as "endomorphosed rock" and recognized the deuteric character of these minerals. Butler (1936, pp. 550-551) questioned the application of the term "endomorphism" to "post-consolidation modification of igneous rock by its own final consolidation residue," a sense in which Gillson and Kania employed the term. He believed it to be restricted to modifications in igneous rock brought about by reaction with the country rock. He wrote, "The process ceases when the marginal portions of an intrusive have become inactive and solidified." As Butler believed formation of the emery took place during the early liquid-magmatic stage of the Cortlandt eruptive, he felt justified in applying this term. However, as the emanations responsible for the formation of the emery and poikilitic silicates appear to have been post-consolidation and the origin of emery was not dependent on interaction of basic magma and country rock, the term "endomorphosed norite" as defined by Butler and others (Holmes, 1928, p. 90) is, therefore, not favored.

Gillson and Kania applied the term hornfels to cordierite-sillimanite rock. Grout (1932, pp. 370-372) defines hornfels as a dense, fine-textured rock in which the original schistosity has been obliterated. The cordierite-sillimanite rock, however, is coarse grained and may have locally retained original schistosity; Butler, therefore, proposed the term meta-schist. As schist is a metamorphic rock, however, Butler's prefix may be misinterpreted, and the rock being the source of the commercial emery the quarrymen's term gray emery is preferred. Tyrrell (1926, p. 291) defines hornfels on the basis of its mineralogical composition; the rock under discussion fits his definition.

Butler (1936) concluded that emery was of contact metamorphic origin, but formed before solidification of the "endomorphosed" norite. His conclusions and supporting observations will be discussed point by point.

1. Emery deposits are (a) "concentrations introduced into . . . exomorphosed schist" (1936, p. 573), (b) "mineralized xenoliths of exomorphosed schist" (1936, p. 573) in norite.

This statement is correct if reference is made to the gray emery, but does not hold for black emery. If magnesium and iron ions had reacted with the original schist, sapphirine, cordierite, and sillimanite would have resulted, not corundum and spinel.

2. Emery was formed by contact metamorphic action of the basic Cortlandt intrusive on the Manhattan schist.

The arguments cited are similar to those put forth by Gillson and Kania. Butler was only concerned with Emery Hill and therefore missed some of the overall relations. Like Gillson and Kania, he did not recognize the importance of hornblendization and biotitization in emery formation.

3. Emery was formed by favorable emanations from the intruding magma.

This conclusion agrees with that of Gillson and Kania. Throughout, Butler speaks of "emanations," "favorable emanations," "emery developing emanations," "emery depositing emanations," but nowhere does he give a clue to the nature or composition of these emanations.

4. Emanations from the Cortlandt magma were released early during the intrusion.

As supporting evidence, Butler cites that emery deposits are mineralized xenoliths engulfed by the advancing magma. This point has already been taken up.

5. The emery deposits were formed before solidification of the enclosing norite.

This is one of Butler's most significant conclusions. Some of his supporting observations will therefore be examined.

a. Norite cuts through the emery and includes fragments of emery.

Microscopic examination of the norite-emery contact shows that emery minerals partially replaced norite; apparently the norite "cross-cutting" the emery did not lie in the paths of the emanations.

b. Emery bodies are transected by Cortlandt dikes and "cooling-shrinkage fractures" healed with deuteric minerals.

The dikes are of granitic composition, while the deuteric minerals, tourmaline, allanite and chlorite, are likely to be related to the granite, not the Cortlandt intrusion. Their presence only indicates that formation of the emery did not take place at a late stage in the granitic intrusion.

c. Deuteric and late-stage emanations tended to destroy, rather than develop, emery.

This observation is correct but relates to emanations from granitic rather than basic sources.

Butler considered postconsolidation emanations responsible for the disintegration of emery minerals. He cited disseminated emery minerals, particularly ramifying corundum crystals, in uralitized contact norite. Sillimanite, biotite and possibly cordierite are said to preserve former spinel crystals altered by magmatic emanations. Emery crystals ramifying through feldspar or pyroxene can, however, be interpreted as formed at the expense of the silicates, while the decomposition of spinel and formation of sillimanite and cordierite are explained by the reaction between spinel and silica.

Butler realized the importance of the modifying influence of later deuteric emanations but failed to trace them to the granitic source. He foresaw the possible role of the granite in emery formation but relied on the literature (Papavasiliou, 1914; Watson, 1923) which gave an incomplete picture of the relationship between the emery and basic rocks. Considering Watson's observation that the Virginia emery is developed in schist and granite near schist-granite contact, he studied the Peekskill granite-Manhattan schist contact. Finding no sign of emery development, he discounted the granite as an important factor.

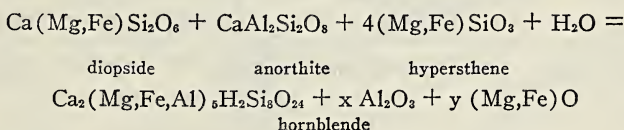
The theories discussed above leave several observations unexplained and a new theory must therefore be proposed which takes into account the regional pattern. For this reason features common to all deposits will be briefly outlined.

The country rocks of the North American spinel-emery deposits are Precambrian or early Paleozoic schists intruded by pyroxenic basic intrusives, followed by granites or granite-pegmatites which cut schist and basic rock. Black emery occurs in irregular lenticular bodies as a replacement of the basic rock, gray emery as a replacement of the schist. Hydrothermal alteration of the associated basic rocks is pronounced.

One of the most characteristic modes of alteration of the basic rocks is their hornblendization which in the outer region of the Cortlandt complex gave way to biotitization. Formation of spinel, magnetite and corundum appears to be related to hornblendization and biotitization. Thin sections of basic rocks from the Virginia emery deposits show the close association of spinel and iron oxides with hornblende and their occurrence as enclosures in crystals which were originally pyroxene, but have been replaced except for small corroded pyroxene

relics. At Cortlandt, Shand (1942, p. 419) has shown that spinel is always enclosed in or intergrown with magnetite in rocks rich in poikilitic hornblende. This was noted particularly in thin sections from his "region of abundant poikilitic hornblende," a distance of 2 miles from a major emery development. Near emery deposits, the oxides as well as hornblende and/or biotite are more abundant than elsewhere in the norite. Magnetite, spinel and corundum crystals ramify here through feldspars and pyroxenes, and unreplaced pyroxene and feldspar relics form small islets surrounded by the oxides. In emery, near the norite-emery border, small unreplaced corroded pyroxene and feldspar crystals are enclosed in emery minerals.

Shand suggested the following equation for the formation of poikilitic hornblende at the expense of the indigenous minerals of the norite:



This equation is to serve for purposes of illustration only; the reaction probably took place between free ions in the presence of hot solutions or water vapor.

Although magnesium, iron and aluminum ions appear to have been released in the process of hornblende or biotite formation, only accessory spinel and magnetite seem to have been concurrently deposited. The ions were probably transported by the emanations to the border of the basic rock bodies. The route of the emanations is indicated by accessory spinel and magnetite.

Particularly intense hornblendization and biotitization took place in the basic rocks near emery. Many deposits are mantled by massive biotite-garnet rocks with 80 to 90 percent biotite. Probably a large part of the emery was therefore formed close by.

An interesting correlation is possible between the above conclusions and the geophysical data obtained by Steenland and Woollard (1952). Their magnetic survey indicated (p. 1085) "a broad, irregular maximum of 1,200 gammas in the central area about 0.7 mile east of the center of the area of poikilitic hornblende" (see Figure 18). Steenland and Woollard are unable to explain this anomaly on the basis of the magnetic susceptibility of the rocks in that area and relate it to a concentration of magnetite in the rocks beneath the complex. However, as the occurrence of poikilitic hornblende and accessory spinel with associated titaniferous magnetite is most pronounced in

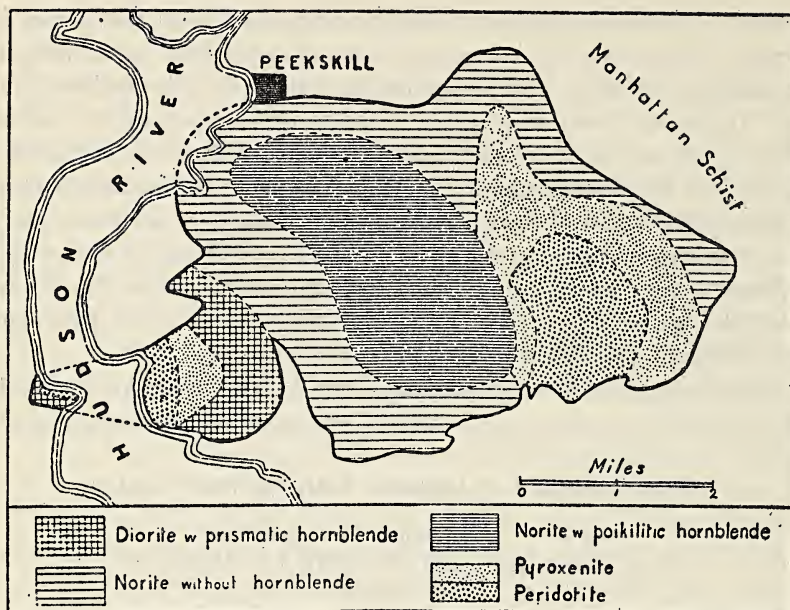


FIGURE 18a. PETROGRAPHIC MAP ACCORDING TO SHAND

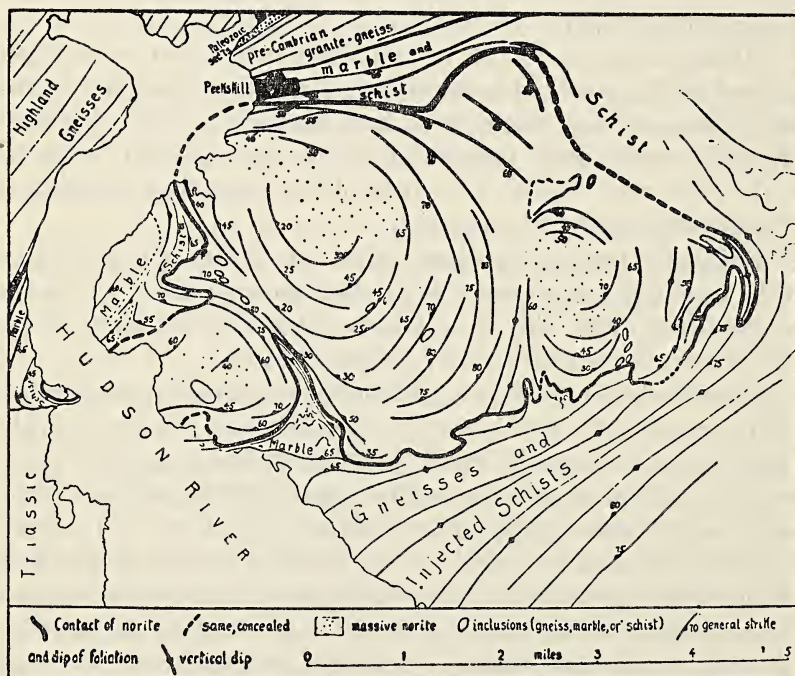


FIGURE 18b. STRUCTURAL MAP ACCORDING TO BALK

MAPS OF THE CORTLANDT COMPLEX

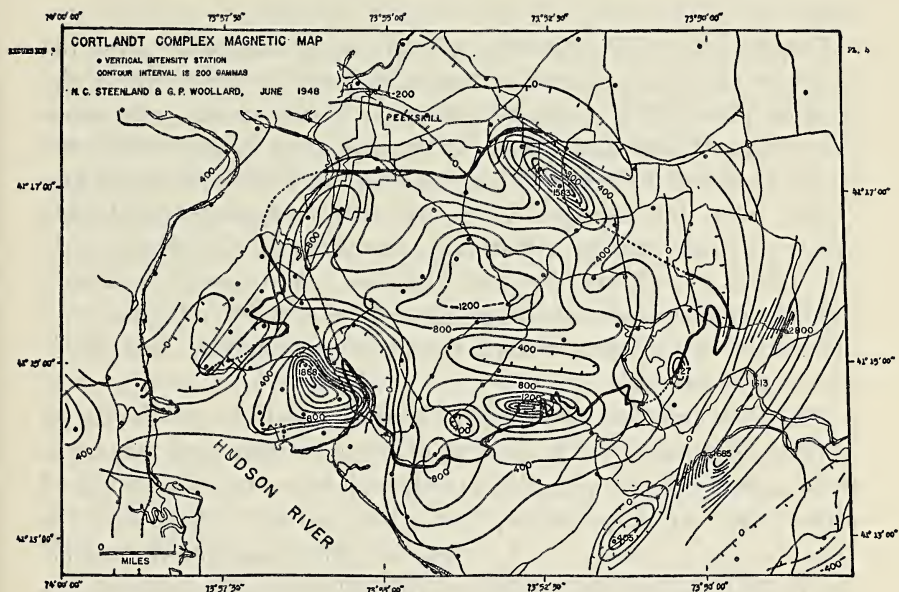


FIGURE 18c. MAGNETIC MAP ACCORDING TO STEENLAND AND WOOLLARD

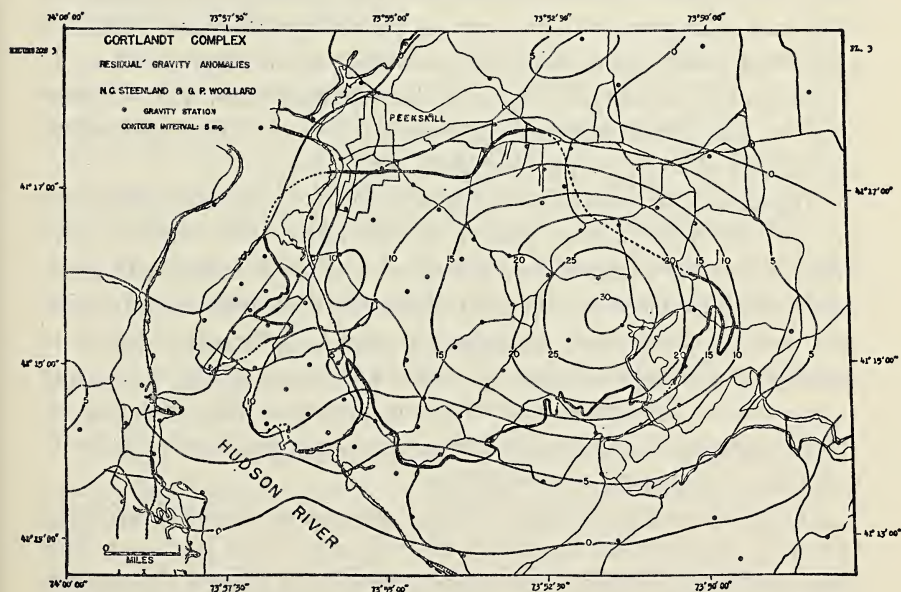


FIGURE 18d. GRAVIMETRIC MAP ACCORDING TO STEENLAND AND WOOLLARD

the central region, the magnetic anomaly may at least in part be attributed to the presence of the iron minerals in the norite of that area.

Steenland and Woollard cite a local magnetic anomaly over the Rosetown extension of the Cortlandt Complex $1\frac{1}{2}$ miles west of the Hudson River. The anomaly readings at Rosetown are only about 200 gammas below those given for the maximum in the central area of the Cortlandt Complex. Steenland and Woollard note that Kemp (1888), who described the Rosetown rocks, mentioned considerable magnetite in association with abundant hornblende. Considering that the central area of the Cortlandt Complex is the area of maximum hornblende abundance and as hornblende, spinel and titaniferous magnetite are related both in time and space, a magnetic anomaly is expected in that area.

The four pronounced magnetic anomalies which are developed along the boundaries of the Cortlandt Complex reflect local concentrations of emery. These anomalies are more or less symmetrically spaced around the central maximum; it seems likely that in the area of the broad irregular maximum of 1,200 gammas the emanations responsible for the formation of the poikilitic hornblende and emery minerals ascended, and from there passed outwards to the boundary of the complex. Disseminated spinel and titaniferous magnetite were left in the norite en route. The observation that the maximum lies about 0.7 mile east of the center of the area of poikilitic hornblende instead of coinciding with it is not disturbing inasmuch as the magnetic anomaly of the emery deposits of Salt Hill lies approximately that distance west of the emery outcrops. Agreement between the petrographic deductions and the geophysical data seems close.

Magnesium, iron and aluminum ions did not stop abruptly at the border with the schist but passed into the latter. The reactions were probably similar to those between spinel and silica near quartz veins. Magnesium-iron ions reacted with silica to form sapphirine and cordierite, and aluminum ions similarly gave rise to sillimanite, kyanite or andalusite. The result of these reactions is the gray emery. A decrease in magnesium, iron and aluminum and an increase in silica with increasing distance from the intrusive border can be shown from both chemical and mineralogical considerations.

The protagonists of "basic fronts," relying on chemical evidence, similarly advocate the migration of magnesium and iron ions from basic rocks into country rock where cordierite is formed (Wegmann, 1935, pp. 327-328; Backlund 1943, pp. 121-122; Reynolds 1947).

As an alternative mode of origin of the emery, removal of silicon ions from the norite may be suggested. This would not explain, however, the close association of spinel and iron oxides with hornblende or biotite and their enclosures in crystals which were originally pyroxene, but have apparently been replaced. Emery formation is apparently linked with hornblendization and biotitization. Similarly, decomposition of amphibole could liberate magnesium, iron and aluminum ions and give rise to emery minerals, but no evidence for such a process has been obtained.

Hornblendization took place after solidification of the basic rocks. Hornblende formed fracture fillings in norite, and Shand (1942, p. 28) furthermore relates "proof that the poikilitic hornblende was formed when the rock was entirely solid is found in some of the rocks that have suffered crushing; for the feldspar shows granulation and mortar structure and has most irregular extinction, while the hornblende plates which ramify through this granulated base have often escaped crushing and show normal extinction." As the emery has apparently developed in the course of hornblende formation, it is therefore later than solidification of the basic rocks.

The source of the emanations that aided the formation of the emery minerals has next to be accounted for. This may be related to (a) the late-magmatic stage of the basic eruptive, (b) the granite intrusion. Collective consideration of the following observations favors their derivation from the granites:

1. Emery deposits only occur in basic rocks associated with younger granites. The consolidation of granite intrusions is often accompanied by the escape of large quantities of volatile constituents, chiefly water. The effect of granitic emanations on the basic rocks is in most cases distinct and manifests itself by the formation of talc¹, alteration of green to blue hornblende¹, and other factors cited below.

2. Tourmaline and allanite, minerals containing constituents usually associated with acid igneous intrusives, are associated with the emery.

3. Formation of corundum has frequently been ascribed to reaction between pegmatite dikes and older basic rocks (Gordon, 1921; Moyd 1949, p. 746; Reichert 1950, p. 81).

4. In the Memesagamesing and Caribou Lake eruptive complexes of Loring, Ontario, Canada (Friedman, in preparation), hornblende abundantly formed at the expense of pyroxenes as at Cortlandt, New

¹Hess (1933) and Stuckey (1950, p. 115) attribute the formation of talc to hydrothermal alterations of basic rocks by granitic emanations. Alteration of green to blue hornblende is similarly explained by Kesler (1944, p. 770).

York, and Whittles, Virginia; hornblendization was particularly intense near granite pegmatite dikes. Similar observations have been made by Reynolds (1946, p. 417).

5. Biotitization is characteristic of the alteration of basic rocks by acid intrusives (Hess, 1933, p. 646). At the Memesagamesing and Caribou Lake complexes near Loring, Ontario, just referred to, abundant biotite was developed near the pegmatite dikes.

6. Although this study is primarily concerned with the spinel-emery, a field and laboratory examination was also made of the spinel-free emery of Chester, Mass. The host rock of the Chester deposits is an amphibolite associated with serpentine. Granites are prominent in the area and Gordon (1921) came to the conclusion that the Chester emery had been developed chiefly by desilication of a granitic pegmatite. Hurley and Goodman (1943, p. 309) determined the age of the magnetite in the emery and arrived at 225 million years. The emery occurs in Ordovician rocks which date back to 350 million years, according to data given by Rodgers (1952, p. 425). Rodgers (p. 416) relying on Emerson's (1898, 1917) interpretation of the origin of the Chester emery, thought the emery to be contemporaneous with the metamorphism of the early Paleozoic host rock and could not square this age discrepancy. However, the age of the granites responsible for the formation of the emery is Carboniferous, which falls in line with the data determined by radio-activity. The criteria used by Gordon for attributing emery formation to the granites are similar to those noted at spinel-emery deposits.

On the basis of the foregoing considerations, it appears that emanations from the granite intrusions, chiefly water, reacted with the indigenous minerals of the basic rocks to give rise to hornblende or biotite and released magnesium, iron and aluminum ions. A solution acting on rock will displace certain ions, while it will not displace others, depending on the differential mobility of the elements. Mobility depends on solubility and refers to the ability of the elements to migrate (to be transported) in the course of chemical changes in the rock.

Korzhinsky (1950*a*) differentiates between two extremes of ionic transportation: (*a*) metasomatic diffusion; (*b*) metasomatic percolation. Percolation is typical of high-temperature conditions when the formation of fissures is impeded. In the Cortlandt Complex, which has a banded structure as noted by Balk (1927), Shand (1942, p. 418) observed that hornblende tends to form in the coarser bands where percolation must have been facilitated. Korzhinsky (1950*b*) expressed his sequence of differential mobility in terms of oxides, whereas trans-

portation may have been effected in the ionic state. The term ionic mobility is therefore favored.

As the more mobile elements in emery formation were the first to be transported to their locus of deposition, a study of paragenesis serves to establish their sequence as follows (listed in order of decreasing mobility): iron, magnesium, aluminum, titanium. Magnetite is the most common and earliest constituent of the emery; spinel is next, followed by corundum; hoegbomite is last, forming at the expense of spinel but never replacing spinel that has been enclosed in corundum. The titanium ions may have been derived from the decomposition of the pyroxenes; as shown by Rogers' analyses (1911, p. 61) the Cortlandt norite is locally high in titanium which is probably largely confined to the pyroxenes. The above sequence is not always sharply defined and there may be overlaps. The formation of the emery near the borders of a basic intrusive may perhaps be explained by a reduction of the solubility of the ions with a decrease in temperature.

Steenland and Woollard (1952) presented a block diagram of the Cortlandt Complex showing a proposed subsurface structure. Their information is based on structural, petrological and geophysical evidence. They suggested that Shand's region of abundant poikilitic hornblende, which Shand considered marks the location of the primary source of the rocks forming the complex, does not represent a funnel through which magma ascended. On the contrary "its structure shows that it was emplaced downward" (p. 1091). Yet this is the area of most prominent post-magmatic alteration and marks the path of the late-stage emanations. As the norite in this region appears to have no great thickness and therefore cannot be underlain by a funnel composed of basic rock, it is possible that a granite mass, such as an extension of the Peekskill granite, may be located beneath the complex. The emanations responsible for the post-magmatic changes in the norite and the formation of the emery bodies appear to have been derived from such a granitic source. This information will hardly change the three-dimensional picture presented by the geophysicists, except for placing an extension of the Peekskill granite beneath the "region of abundant poikilitic hornblende." As the dip of the rocks in this area is toward the center, the ascending emanations could have followed the bands in the norite toward the outer regions of the Cortlandt Complex.

Since there are abundant instances of basic rocks intruded by younger granites or granite pegmatites, many of which have been hornblendized and/or biotitized, it seems surprising that emery deposits are comparatively rare. Although it is important to take cognizance of this

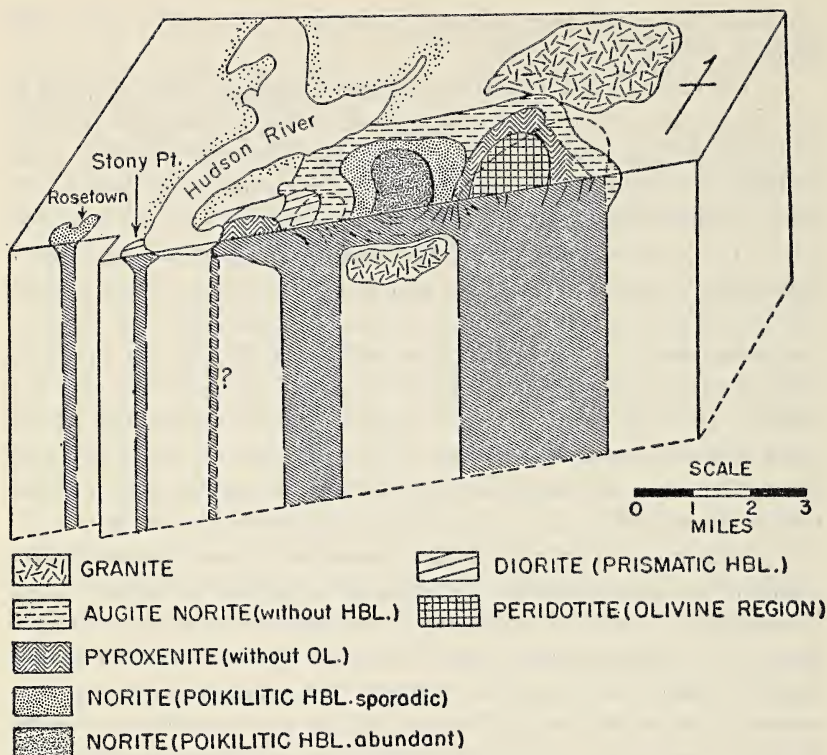


FIGURE 19. Block diagram showing possible subsurface structure of Cortlandt Complex (modified from Steenland and Woollard).

fact, a good solution cannot be offered. It is likely that complex physico-chemical conditions, apparently only rarely attained, are the determining factors.

Summarizing, emanations, chiefly water, from the granites appear to have reacted with the indigenous minerals of the basic rocks to give rise to poikilitic silicates and magnesium, iron and aluminum ions. The ions were transported by the solutions to the borders of the basic rocks where emery was formed. Ions that passed into the adjoining schist reacted with the silica of the schist to form the zoned gray emery.

For the foreign spinel-free emery deposits which are located in a limestone the above theory probably does not hold. However, it is possible that a similar mode of origin may be invoked for several foreign spinel-emery occurrences.

Table 7 (p. 62) summarizes the principal theories on the origin of the spinel-emery.

CONCLUSIONS

North American emery deposits are confined to the Appalachian belt and have formed by replacement of basic rocks. Spinel-emery is found in pyroxenic basic intrusives; the spinel-free emery of Massachusetts occurs in amphibolite or serpentine.

Recent theories dealing with the origin of the Cortlandt spinel-emery consider it to have formed by contact metamorphism. These theories do not give a clue to the reactions involved in emery formation but suggest that the emery-depositing emanations are related to the Cortlandt magma. A new theory of origin for the spinel-emery is proposed which takes into account the regional pattern. The host rocks of the North American emery deposits are norite, gabbro and perhaps peridotite which intrude Precambrian or early Paleozoic schists and are in turn cut by granites or granite pegmatites. Foreign spinel-emery deposits show a similar pattern of occurrence, but the important foreign commercial emery deposits are spinel-free and occur in limestone.

Granitic emanations working on the consolidated basic rock caused the formation of poikilitic hornblende and/or biotite and released magnesium, iron and aluminum ions which gave rise to the emery. The genetic relationship between the poikilitic silicates and the emery minerals is indicated as follows:

Spinel and titaniferous magnetite, which make up between 70 and 100 percent of most emery deposits, are commonly found disseminated in the norite in association with the poikilitic silicates, and are locally enclosed with them in the corroded primary norite or gabbro minerals. Shand's equation indicates that an excess of Mg, Fe, and Al is left behind when hornblende is formed. Near emery deposits, the emery minerals together with the poikilitic silicates abundantly replaced pyroxenes and feldspars.

The emery formed after solidification of the norite because:

1. The poikilitic hornblende (which is contemporaneous with the emery) forms fracture fillings in the Cortlandt norite.
2. In rocks that have suffered crushing, the hornblende has locally escaped crushing and ramifies through the granulated base.

The source of the emanations responsible for emery formation is granitic because:

1. Emery deposits only occur in basic rocks associated with younger granites.
2. The presence of such minerals as tourmaline and allanite is indicative of granitic emanations.

TABLE 7
Principal theories on the origin of the spinel emery

DATE:	1912	1930	1936	PRESENT STUDY
AUTHOR:	ROGERS	GILLISON & KANIA	BUTLER	FRIEDMAN
Theory: Absorption of Manhattan schist by Cortlandt magma with resultant aluminous segregations		Deuteric contact metamorphism	Contact metamorphism "during the early liquid-magmatic stage of the basic Cortlandt intrusives"	Alteration of the basic rocks by granitic emanations formed hornblende and/or biotite at the expense of the primary minerals of the basic rocks, and released Mg, Fe and Al ions which gave rise to the emery.
Evidence: R. quotes experiments on artificial production of corundum performed by Morozewicz.		1. Emery and associated rocks contain common contact minerals. 2. Emery occurs only with endomorphosed igneous rocks. 3. The paragenesis is characteristic of contact metamorphic processes. 4. Locally the emery occurs so far from the contact "as to preclude the possibility of (its) formation by magmatic reaction." 5. The feldspar in emery is andesine, not labradorite. This could not have resulted from an equilibrium between norite magma and schist. 6. Quartz and corundum occur in the same rocks. They would have combined to form an aluminum silicate if formation by reaction and assimilation had taken place.	The arguments for contact metamorphism are similar to those presented by G. & K. The emery was formed early during the intrusion because: 1. Emery deposits in hornfels and mixed rock are near norite. 2. Emery deposits in norite are mineralized xenoliths engulfed by the magma. The emery was formed before solidification of the endo-morphosed norite because: 1. The emery in norite occurs only in xenoliths of exomorphosed schist. 2. No emery veins were found in norite. 3. Norite cross-cuts emery lenses and encloses emery fragments. 4. Emery bodies are transected by	The emery was formed at the expense of the basic rock, and Mg, Fe and Al ions which gave rise to the emery are genetically related to poikilitic hornblende and/or biotite because: 1. Spinel and titaniferous magnetite in norite are commonly associated with the poikilitic minerals and are locally enclosed with them in the corroded primary norite minerals. Shand's equation indicates that an excess of Mg, Fe and Al is left behind when hornblende is formed. Near emery deposits the emery minerals together with the poikilitic silicates abundantly replaced pyroxenes and feldspars. The emery formed after solidification of the norite because: 1. The poikilitic hornblende (which is contemporaneous with the emery) forms fracture fillings in the norite.

DATE:	1912	1930	1936	PRESENT STUDY
AUTHOR:	ROGERS	GILLISON & KANIA	BUTLER	FRIEDMAN
		7. The mineral suite present indicates an origin by emanations.	dikes and fractures healed with deuteric minerals. 5. Deuteric and late-stage emanations tended to destroy, rather than develop emery.	2. In rocks that have suffered crushing the hornblende has escaped crushing and ramifies through the granulated base. The source of the emanations responsible for emery formation is granitic because: 1. Emery deposits only occur in basic rocks associated with younger granites. 2. The presence of such minerals as tourmaline and allanite is indicative of granitic emanations. 3. The presence of talc, sodic hornblende and abundant biotite in the basic rocks is indicative of metasomatic alteration by granite emanations. 4. The formation of the Massachusetts spinel-free emery, similarly located in basic rocks, can be related to younger granites by helium-age measurement. 5. Corundum formation has frequently been ascribed to the reaction between granitic bodies and older basic rocks. 6. The present theory can be explained in the light of the three-dimensional shape of the Cortlandt Complex.

3. The presence of talc, sodic hornblende and abundant biotite in the basic rocks is indicative of metasomatic alteration by granitic emanations.

4. The formation of the Massachusetts spinel-free emery, similarly located in basic rocks, can be related to younger granites by helium age measurement.

5. Corundum formation has frequently been ascribed to the reaction between granitic bodies and older basic rocks.

6. The present theory can be explained in the light of the three-dimensional shape of the Cortlandt Complex.

Summarizing, reactions invoked in the basic rocks by granitic emanations caused the formation of hornblende and/or biotite and the release of Mg, Fe and Al ions which gave rise to the emery. At Cortlandt, the emanations appear to have ascended in the region of Shand's "area of poikilitic hornblende," and then followed the bands in the norite toward the outer region of the complex. Mg, Fe and Al ions that passed into the adjoining Manhattan schist reacted with the silica to give rise to the zoned hornfels of the Cortlandt aureole.

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in

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By

D. P. CONNOLA D. L. COLLINS J. H. RISLEY W. E. SMITH

NEW YORK STATE MUSEUM
AND SCIENCE SERVICE

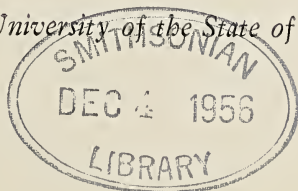
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INSECT DAMAGE AND ITS PREVENTION IN WINDTHROWN SAW TIMBER

By

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Following the severe windstorm of November 25, 1950 which resulted in heavy blowdown of timber on 343,000 acres in the Adirondack Mountains, the New York State Science Service, in cooperation with the New York State Conservation Department, established observation and experimental plots in blowdown areas near Stratford in Fulton County to study the course of insect attack on windthrown timber and methods of preventing attack while the timber was being salvaged. The study had two phases: (1) ecological studies to determine the species of insects which attacked the down timber, and (2) control studies to determine whether large-scale insect buildup and attack could be reduced or prevented.

Some of the early studies were described in the paper "Survey and Control Studies of Beetles Attacking Windthrown Trees in the Adirondacks," by D. P. Connola, C. J. Yops, J. A. Wilcox and D. L. Collins (*Journal of Economic Entomology*, Vol. 46, No. 2, April 1953). Additional information from the study plots was given in an unpublished report entitled "Subcortical Insects Associated with Recently Windthrown Spruce in the Adirondacks," by Robert K. Bennett. These two reports constitute the background for the studies described below.

The present report covers three phases of work: (1) observations on the activities of wood-boring insects and the extent of their attack as affecting the salvability of the blowdown timber; (2) mill studies of salvaged timber to evaluate the insect damage in the cut lumber and correlate it with the data from superficial observations; (3) studies in the control of the insects which attack the logs.

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1. *Observations on the activities of wood-boring insects and the extent of their attack as affecting salvability of the blowdown timber.*

The investigations were carried on in blowdown areas in the Adirondacks from November 1952 to August 1953. In these investigations, logs and trees in the blowdown areas were examined for insect attack and condition of bark and wood. The sampling procedure was the removal of one square foot of bark from the top, center and butt sections of each log or tree, but not from the same face. The three debarked areas were then examined for beetle entries into the wood. The types of beetles attacking were determined and the numbers of entries of each type were recorded.

Although most of the tree species growing in the Adirondacks were involved in the blowdown, red spruce suffered by far the greatest amount of windfall. Other species which suffered considerable blowdown were eastern hemlock, balsam fir, eastern white pine, sugar maple, yellow birch and American beech. Since windthrown trees apparently died from the top down, most insect attack started in the crown and progressed to lower portions of the bole as breeding conditions became suitable for the various insect species. Ambrosia beetles seemed to attack all parts of the bole as soon as the trees began to die, and continued their attack as long as the bark was green or the wood sufficiently unseasoned to support the growth of ambrosia fungi.

Insect invasion of the softwoods began in the spring of 1951 and increased in 1952. Attack was made by ambrosia beetles, bark beetles and borers. Greatest damage to wood the first season was by ambrosia beetles. The wood borers (Cerambycidae) were primarily larvae under the bark and did not enter the wood to any great extent until late in the season. In 1952, although ambrosia beetles and wood borers continued to attack unseasoned timber, wood borer damage became more evident not only from damage occurring in the wood but also from the presence of holes made by emerging adults during the season.

Tetropium cinnamopterum Kby. (the eastern larch borer) (figure 3) was the most common of the various wood borers found attacking red spruce. Craighead (1950) stated that the species is not of much economic importance. In an earlier publication (Craighead 1923) he reported that the mines of the species are constructed entirely under the bark of coniferous trees and their short pupal cells are made in the outer sapwood and bark. Felt (1906), quoting Hopkins, says that the species infests the green bark and wood of injured and dying spruce in West Virginia and that it is very injurious since it hastens the death of the trees. In our studies, the larvae usually penetrated 2 to 3 inches,

sometimes deeper, into the wood, (figure 21). *Monochamus scutellatus* Say (the white-spotted sawyer) (figures 4 and 15) was found attacking red spruce, white pine and balsam fir. Larvae of this species were found to a depth of 4 inches. *Monochamus notatus* Drury (the northeastern sawyer) (figure 16) was found in red spruce but it was more common in white pine, at depths of 4 to 7 inches (figures 17, 18 and 22). *Monochamus* emergence holes were commonly found in the crown portions of the boles of down spruce. The emergence holes are much larger than those of *T. cinnamopterum*.

Our observations on borers were confined to windthrown trees. However, Felt (1906) found *M. notatus* larvae in the bark of a live, apparently healthy white pine. Injury to the tree was indicated by pitch masses on the bark at the points of attack. The tree was not attacked by any other species of insect.

Ambrosia beetle attack on red spruce, white pine, hemlock and balsam fir was by two species, *Gnathotrichus materiarius* Fitch (the eastern pine wood stainer) and *Trypodendron bivittatum* Kby. (the spruce timber beetle) (figures 9 and 13). Both species usually penetrate the wood to a depth of 2 to 3 inches (figures 10, 14, 19 and 21). Occasionally, some galleries may be deeper. The hole made by *G. materiarius* is about the diameter of the standard lead used in mechanical pencils. The hole made by *T. bivittatum* is slightly larger. The wood stains from the fungi growing in the galleries are often more of a factor than the holes themselves in degrading lumber. Snyder (1927) refers to yellow poplar streaked with such stain as "calico poplar." As with oak, because of its pleasing effect, it may be sold for paneling. For such a purpose there would be little or no loss in grade.

In 1953 new attack on softwood down timber dropped to a very low level and by the end of the season was negligible in most areas. Although on occasion bark beetle and borer larvae could be found in the bark, the bark was generally no longer suitable for further attack. Borer larvae were found in the wood but they were probably from eggs laid in 1951 and 1952. Ambrosia beetles continued to attack, but in smaller numbers, and most of the attack appeared to be on unseasoned timber with bark still partly green.

Other than attack by *Monochamus* and one or two species of minor importance, most insect damage to softwood blowdown did not penetrate more than 2 or 3 inches into the wood. In timber of large diameter, there was sufficient sound wood to make salvaging profitable.

It may be well to note here the wood borer activities as associated with bark beetle activities in bark of softwood blowdown timber.

Many wood borers such as *Tetropium* and *Monochamus* spend the early part of their larval stage feeding under the bark before entering the wood. In doing so, they come into direct competition with other bark boring insects for food, and their populations thereby become limited. In 1951, the first season after the blowdown, windthrown red spruce, besides being attacked by borers and ambrosia beetles, was generally attacked by two secondary species of bark beetles, namely, *Polygraphus rufipennis* Kby. (the four-eyed spruce bark beetle) (figures 5 and 6) and *Dryocoetes piceae* Hopk. There were other species which attacked locally but they were fewer in number. The combined attacks greatly speeded the deterioration of the bark on the down trees, and made it unsuitable for further breeding.

Attack on the hardwoods was light or absent until 1952. Most of the windthrown hardwoods that had their roots still partly in the ground were alive, growing and free of insect attack during 1951. In 1952, the trees started to weaken and ambrosia beetle attack began. By 1953, except where partially uprooted trees had access to sufficient moisture to keep them alive, down hardwoods in most areas were dead or dying and were being attacked by ambrosia beetles. In some places the attack was heavy. Such attack and the staining of the wood by the ambrosia fungi growing in the beetle galleries degraded the outer, valuable layers of wood to a point where salvaging of such timber was unprofitable. The ambrosia beetle which caused the most damage was *Xyloterinus politus* Say, which often penetrated into the wood to a depth of 4 or 5 inches (figures 11, 12 and 20). The usual depth was about 3 inches. Chamberlin (1939) lists 10 broadleaf tree species which are reported as hosts of this insect but questioned the reported attack on *Pinus* and *Picea*. In our studies we found that it attacked red spruce (*Picea rubra*) on rare occasions.

Another species, *Monarthrum mali* Fitch, which was found attacking hardwoods but to a lesser degree, penetrated wood to about the same depth (figures 7 and 8). However, it makes a much smaller hole than that of *X. politus* and, except for staining, its damage may not be so serious.

Some borer attack (by cerambycid and buprestid larvae) was found in hardwood blowdown in 1953 but was inconsequential as compared to the activities of ambrosia beetles. *Xylotrechus colonus* Fab. (the rustic borer) was common in yellow birch. When found in the wood, its penetration was confined to the first inch, which would be removed with the slab in milling.

Examination of windthrown trees in some areas of heavy or complete blowdown indicated that insect attack was limited or prevented,

particularly in the upper side of the boles, by the exposure of the down trees to sun and drying out. Under very dry conditions the bark soon became unsuitable for attack and timber remained salvable for a longer period.

2. *Mill studies of salvaged timber to evaluate the insect damage in cut lumber and correlate it with the data from superficial observations.*

The observations made in 1953 on the extent of insect attack on the windthrown timber in the woods were followed by studies made to correlate the type and intensity of attack with the actual damage occurring in lumber cut from salvaged logs.

Since red spruce was the major species involved in the blowdown, the emphasis was on studies of this species. Three northern New York sawmills which were milling salvaged red spruce cooperated in this project. All three mills used a circular saw and cut their logs into lumber in the conventional manner.

A total of 47 red spruce logs which varied from 10 to 20 feet in length and showed insect damage externally or internally, or both, were used in the study. The diameters of these logs ranged from 6 to 19 inches and averaged 11.4 inches on the small end. The logs were examined prior to processing so that a record of the extent of attack by ambrosia beetles and borers on each log was obtained. This was done by debarking 1-square-foot sample areas from the center and near the two ends of each log and examining the three sample areas for entries into the wood. The counts from the three sample areas were averaged to give the intensity of attack on the log by each insect. The ambrosia beetle damage in the logs was by *Gnathotrichus materiarius* Fitch and *Trypodendron bivittatum* Kby., the former being more prevalent. The borer damage was primarily by *Tetropium cinnamopterum* Kby., with an insignificant amount by *Monochamus* sp.

As each log was sawed, the lumber was graded according to the amount of insect damage found in the boards. Borer damage and ambrosia beetle damage were tallied separately. A total of 4,245 board feet of lumber was cut from the 47 logs and the boards were graded as follows:

AMOUNT OF BOARD SURFACE DAMAGED BY INSECTS	DEGREE OF DAMAGE
Less than $\frac{1}{4}$	light
$\frac{1}{4}$ to less than $\frac{1}{2}$	medium
$\frac{1}{2}$ or more	heavy

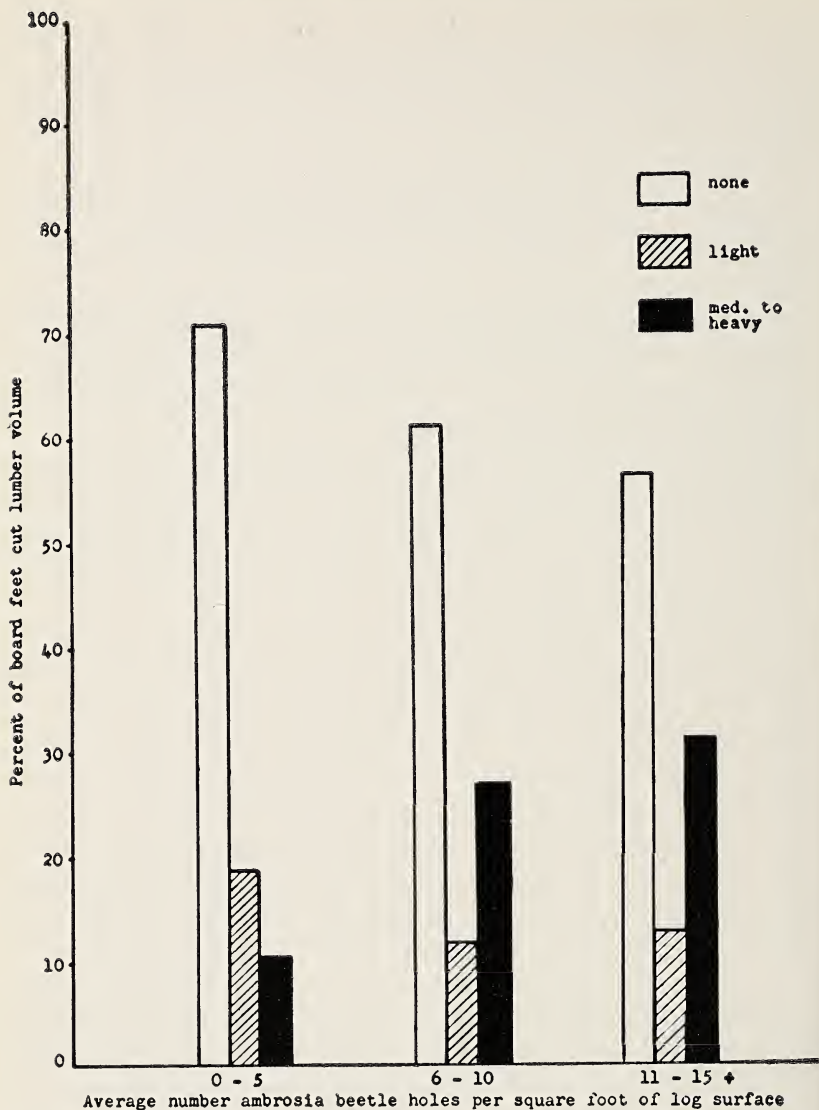


Figure 1. Analysis of ambrosia beetle damage in cut lumber (red spruce) based on intensity of attack on the logs. Each bar shows percent cut volume and the degree of damage (see key) for each of the intensity-of-attack classes.

In order to correlate the damage occurring in the cut lumber with insect attack as noted on the surface of the logs, an arbitrary classification of the intensity of attack on the logs was set up. Thus, for ambrosia beetle attack there were three classes, namely, 0 to 5, 6 to 10, and 11 to 15 + holes per square foot of log surface. The first class included 0 because the sampling on two of the very lightly attacked logs did not show

ambrosia beetle attack, yet damage by the insect was revealed in the lumber cut from them. This also occurred in the classification of borer attack. Two logs which showed no borer attack by sampling had borer damage in their lumber. Two arbitrary classes were set up for borer attack: 0 to 2, and 3 to 6 holes per square foot of log surface.

Figures 1 and 2 are graphs which show the correlation between intensity of insect attack as measured by the log sampling and the damaged and undamaged cut lumber volumes from the logs. Both graphs indicate a decrease in undamaged volume as the intensity of attack by ambrosia beetles and borers increased. Graph 1 shows that there was a sharp rise in medium to heavy ambrosia beetle damage as the intensity of attack increased. There was more light damage than medium to heavy in the 0 to 5 holes per square foot class but more medium to heavy damage as the intensity of attack increased.

A comparison of the graphs in figures 1 and 2 brings out the fact that fewer borers than ambrosia beetles were required to damage a given volume of wood. Thus the undamaged volume in logs which had 0 to 2 borer holes and 3 to 6 borer holes was about the same as the undamaged volume in logs which had 6 to 10 and 11 to 15 + ambrosia beetle holes, respectively, per square foot of surface. However, in the damaged volumes, with the same classes for comparison, there was more light than medium to heavy damage by the borers, whereas the opposite was true with the ambrosia beetles. Table 1 contains the values used in graphs 1 and 2.

To gain more information on the depth of penetration by ambrosia beetles and borers after they entered the wood, a study was made of infested logs at one of the mills to determine the number and location of damaged boards from the logs and the extent of damage in each

TABLE 1—RED SPRUCE

Analysis of mill data in the study of ambrosia beetle and borer damage to cut lumber volume, based on the intensity of attack on the logs. (Average diameter of logs: 11.4 inches)

AV. NO. HOLES PER SQ. FT. OF LOG SURFACE	PERCENT OF CUT VOLUME SHOWING THE INDICATED DEGREES OF DAMAGE		
	NONE	LIGHT	MEDIUM TO HEAVY
<i>ambrosia beetle</i>			
0— 5 (27 logs)	71.0	18.6	10.4
6—10 (7 logs)	61.2	11.8	27.0
11—15 (4 logs)	56.2	12.7	31.1
<i>borer</i>			
0— 2 (27 logs)	63.5	20.6	15.9
3— 6 (14 logs)	57.7	22.6	19.7

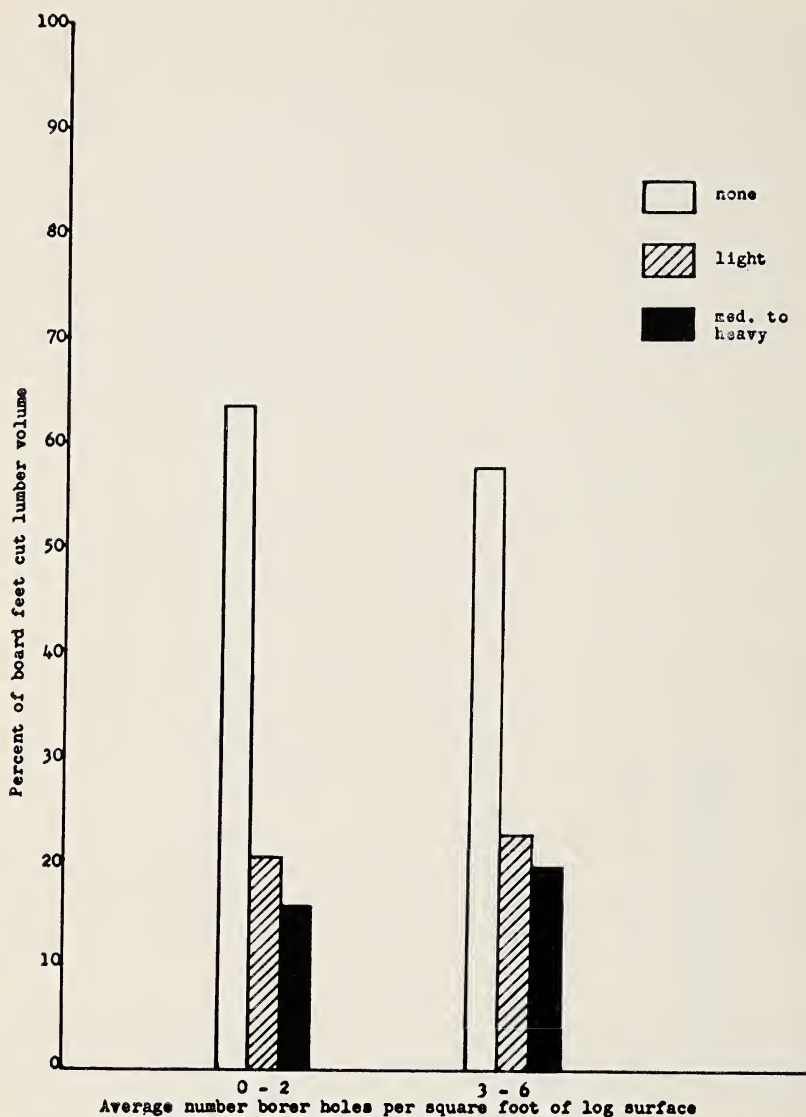


Figure 2. Analysis of borer damage in cut lumber (red spruce) based on intensity of attack on the logs. Each bar shows percent cut volume and the degree of damage (see key) for each of the intensity-of-attack classes.

board. The boards were classified according to their position in the logs as they were removed by the saw. Thus, the first board removed after the slab was called the first board; the next one, the second board; the following, the third, and so on. Table 2 shows the distribution of 110 insect-damaged red spruce boards from 25 logs classified according to their positions. Most of the boards damaged by ambrosia beetles

TABLE 2

Distribution of insect-damaged red spruce boards as related to their position in the logs; based on examination of 110 damaged boards from 25 logs

POSITION OF BOARDS	NUMBER OF BOARDS EXAMINED WITH							
	AMBROSIA BEETLE DAMAGE				BORER DAMAGE			
	TOTAL	LIGHT	MED.	HEAVY	TOTAL	LIGHT	MED.	HEAVY
1	64	30	25	9	39	15	17	7
2	26	21	4	1	20	16	3	1
3	11	11	0	0	7	7	0	0
4	1	1	0	0	0	0	0	0
5	0	0	0	0	0	0	0	0
6	0	0	0	0	0	0	0	0
TOTAL	102	63	29	10	66	38	20	8

and borers were first boards, and of these there were about as many boards with medium damage as with light damage. There were about half as many second boards showing damage and these showed about as many lightly damaged boards as the first boards, but there were fewer with medium damage. Third boards damaged were fewer than second boards and all of them showed only light damage. Damage to fourth boards was insignificant; fifth and sixth boards had no damage.

Heavy damage did not appear in the boards to the same extent as light and medium damage. Most of the few boards with heavy damage were first boards; only two were second boards.

It may be concluded from study of the data in table 2 that, assuming the thickness of each slab and board to be one inch, the most frequent depth of penetration was 2 inches, this being reflected in the higher damage figure for first boards. These findings agree with observations in the field on the penetration of ambrosia beetles and borers into red spruce, as described above. The two ambrosia beetles, namely *Gnathotrichus materiarius* Fitch (the eastern pine wood stainer), and *Trypodendron bivittatum* Kby. (the spruce timber beetle), and the eastern larch borer (*Tetropium cinnamopterum* Kby.), the most common borer attacking windthrown spruce in the Adirondacks, were found to penetrate down timber to a depth of 2 to 3 inches. Occasionally their galleries penetrated deeper but the most frequent depth was 2 inches. The deeper penetrations account for the damage which occurred in second and third boards.

In order to determine whether the relationship between the number of entries and the resulting damaged volume which occurred in red spruce prevailed also with other tree species, studies of white pine and hardwood logs were made at four mills which were cutting wood

TABLE 3

Mill studies on salvaged blowdown timber other than red spruce

DATA COLLECTED	STUDIES AT MILL NO.				
	1	2	3	4	4
1. Tree species milled	WP	WP	SM B	YB, RM, Bl.C.	YB
2. No. of logs	10	10	3	7	10
3. Av. diameter of logs in inches	20.7	13.5	18.0	17.0	15.0
4. Av. no. of ambrosia beetle holes per sq. ft. of log surface	4.9	8.3	3.3	7.3	0.8
5. Cut lumber analysis for ambrosia beetle damage					
a) % with no damage	84.4	73.3	66.3	63.0	94.8
b) % with light damage	10.5	22.7	23.8	25.0	5.2
c) % with medium damage	2.8	3.7	8.2	10.0	0.0
d) % with heavy damage	2.3	0.3	1.7	2.0	0.0
6. Av. no. of borer holes per sq. ft. of log surface	2.5	0.1	0.0	0.4*	0.0
7. Cut lumber analysis for borer damage					
a) % with no damage	67.7	96.1	100.0	100.0	100.0
b) % with light damage	18.4	3.9	0.0	0.0	0.0
c) % with medium damage	11.1	0.0	0.0	0.0	0.0
d) % with heavy damage	2.8	0.0	0.0	0.0	0.0

* Evidently shallow holes since no damage was found in cut lumber.

Tree species abbreviations used in table:

B—beech; Bl. C.—black cherry
RM—red maple; SM—sugar maple
WP—white pine; YB—yellow birch

in the conventional manner, with circular saws. Results of these observations, which are summarized in table 3, indicate that the differences in the relationship between entries and damaged volume are sufficient, among the different tree species, to make it misleading to attempt to predict from data on red spruce what could be expected in the other species.

In accounting for the differences, in addition to tree species, the following factors appear to be important, and determine how much cut volume from a log may be expected to contain insect damage, and to what extent: (1) the species of insect attacking; (2) the intensity of insect attack; (3) the diameter of the log; (4) the technique used in cutting the log into lumber.

Since each insect species has its own peculiar boring habits, which may be either similar to or different from those of another species, the

species which is attacking will usually determine the depth of penetration into the wood. For instance, the habits of the ambrosia beetle, *Xyloterinus politus*, which was found most commonly attacking hard-wood blowdown, are different from those of *Gnathotrichus materiarius* and *Trypodendron bivittatum* which attack the softwoods, (figures 10, 12 and 14). Typical penetration of *X. politus* is deeper, and although the galleries are usually about 3 inches deep, they have often been found to penetrate 4 to 5 inches. Thus, more damaged volume in logs would be expected with *X. politus*.

The data on the red spruce mill studies as presented in figures 1 and 2 clearly indicate that the intensity of insect attack influences the amount of damage in a log. As the intensity of attack increases, both the volume of damaged lumber and its degree of damage increase.

The diameter of a log is important in determining the percent of cut volume expected to be damaged in the log once the depth of penetration by the attacking insect, together with its intensity of attack, is known. Logs of small diameter will naturally show a greater loss in percent volume damaged than logs of large diameter. In other words, the percent of cut volume damaged becomes a progressively smaller portion of the total cut volume as the diameter increases.

In considering technique in cutting lumber as an important factor, much depends on the equipment used in cutting the logs and the craftsmanship of the sawyer. Often all or most of the insect damage is concentrated on one face of a log and with proper manipulation the damage can be removed so that the least number of boards will be affected, thereby reducing the damaged volume of cut lumber. Also, some mills are equipped to cut small dimension stock, thereby utilizing to a greater extent the outer layers of wood from logs. This results in a greater cut volume from the logs. Since most of the insect damage is found in the outer layers, small dimension cutting would add to the damaged volume of cut lumber from logs.

Considering the four factors outlined above as criteria for grading and scaling insect-damaged logs, if maximum value is to be obtained, it is very important for log graders and scalers to become familiar with the types of insects and damage which occur in a given logging area and the depths in the wood at which the damage is found. This must be done for all tree species since most insect species have a host plant preference, and their attacks are made primarily on those plants. Once the insects and their habits become familiar to the log scaler, damage can be culled or logs graded on the basis of type of damage, intensity of attack and the rules regarding exterior defects. On logs with all or nearly all of the bark intact, the removal of one square foot of bark at

6-foot intervals should give a fair idea of insect attack on the wood; the sampling should not all be done on the same log face if it can be avoided. Short logs should have at least two samples.

3. *Studies in the control of insects which attack logs.*

The possibility of preventing insect attack by application of chemicals has been studied by many workers. Recent work with the newer chlorinated insecticides has shown greater promise than the older materials seemed to offer. Under northeastern conditions, Simpson in New Brunswick (1951) reported that 5 percent DDT in fuel oil, while it did not completely prevent borer attack in softwoods, greatly reduced or delayed it for one season. Becker in Massachusetts, from work done from 1948 through 1952 (published in April 1955), reported that an aqueous emulsion of 0.4 percent gamma BHC gave complete protection against insect attack for the season, when logs were sprayed individually to the runoff point. Connola *et al.* (1947) found in their experiments that diesel oil (one of the common solvents for the toxicants used in later work) alone gave appreciable protection from elm bark beetles when applied in the spring to elm logs in the field.

During the study of the physical results of insect attack on the wind-thrown timber, as reported here, experiments in the control of the insects were also made. Results of some of these tests have been reported, as noted above, in the paper "Survey and Control Studies of Beetles Attacking Windthrown Trees in the Adirondacks." The data presented in that paper showed that general application by helicopter of 2 pounds of DDT per acre, or 0.2 pound lindane per acre, to blowdown timber in May, June and July 1951 failed to reduce beetle attack on the down timber. Application of 4 pounds DDT per acre, or of 0.4 pound of gamma isomer benzene hexachloride per acre by airplane on June 3 and again on June 24, 1952, also failed to reduce attack. However, hand spray experiments, made May 30 and June 12, 1951, with a 3-gallon compressed air sprayer at 35 lbs. pressure, showed that topical applications of emulsifiable lindane in water to the bark of wind-thrown red spruce were effective in preventing beetle attack. With complete spray coverage on the boles of uninfested trees, dosages of $\frac{1}{2}$ to 1 percent lindane gave good protection for 15 months. Complete protection was obtained from the June treatments. The May treatments allowed a few ambrosia beetle entries.

Since results of these early tests indicated satisfactory protection of windthrown trees from beetle attack by thorough coverage of the bark with spray, plans were made for treating freshly sawed logs.

Until recent years, logging was primarily a winter operation because of the comparative ease in transporting the logs over frozen or snow-covered ground. Now, with modern machinery, logging is carried on all year. With summer logging have come new insect problems, and old problems have become intensified. Ambrosia beetles and borers attack logs almost as soon as they are cut in spring and summer, and a delay between cutting and processing of the logs may result in considerable insect damage. Even a two-week delay may result in ambrosia beetle attack which appears as damage in the cut lumber. With veneer logs it is, of course, especially important that logs be processed within a few days after they are cut, or protected in some way against insect attack.

With these considerations in mind, experiments were set up in a blowdown salvage area in which logs with active insect attack and freshly cut logs with no insect attack were sprayed with several of the newer insecticides. Since red spruce was so extensively involved in salvage operations throughout the Adirondacks, and especially since much of it would be stored before it was processed, the sprays were applied to this species. The logs were cut and sprayed on July 17, 1952.

For ease in handling, 8-foot lengths were used. These came from infested and noninfested red spruce leaners. Attack on the infested leaners by *Polygraphus rufipennis*, the four-eyed spruce bark beetle, had begun that year. Insect activity had been progressing for some time and many bark beetle galleries with live larvae were present in the bark although the tops of the leaners were still green. The roots of the noninfested leaners were sufficiently in contact with the ground so that the trees were still growing.

A 2¾-gallon Hudson P.C.O. sprayer with T-jet nozzle and a Smith knapsack sprayer with cone nozzle were used to spray the logs with the following formulations:

Aqueous emulsions: (A) 0.1 percent endrin; (F) 0.1 percent isodrin; (C) 6 percent DDT.

Kerosene solutions: (G) 1.25 percent lindane; (E) 6 percent DDT; (B) 12 percent DDT.

Treatments A and F were applied with the knapsack sprayer; treatments B, C, E and G with the P.C.O. sprayer.

The endrin and isodrin sprays were made from an 18.5 percent emulsifiable concentrate. The DDT kerosene sprays were made by dissolving DDT, at the rate of 1 pound in 1 quart in Sovacide B, then diluting with kerosene. The DDT emulsion spray was prepared from a concentrate in which 3 pounds of DDT were dissolved in ¾ gallon of Sovacide B to which was added 2 ounces of Triton X-100 emulsifier.

The lindane spray was prepared from a solution containing 20 percent gamma BHC (from lindane).

All logs were given complete coverage of spray to the runoff point. Approximately 1 quart of spray was necessary to cover completely each 8-foot log. The logs were treated where they were cut and were left in the woods throughout the experiment. Since they were located in a blowdown area of the Adirondacks (Arietta) they were subject to attack by the usual insects that were attacking the blowdown timber.

In the uninfested log series, each treatment included 3 logs. In the infested series, 3 logs were treated with 0.1 percent endrin water emulsion, 3 with 0.1 percent isodrin water emulsion, 3 with 12 percent DDT in kerosene and Sovacide and 1 with 1.25 percent lindane in kerosene. There were also 3 infested and 3 uninfested untreated or "check" logs included in the experiment.

The infested logs were examined on August 13, 1952, about a month after treatment. Examination of $\frac{1}{4}$ square foot bark samples removed from each log showed that all of the treated logs as well as the 3 untreated check logs had living *Polygraphus rufipennis* larvae, pupae and adults in their bark. Only the lindane-treated log contained some dead

TABLE 4

Results of tests with uninfested red spruce logs sprayed for prevention of insect attack

Sprays applied—July 17, 1952					Examination of logs—Oct. 20, 1953				
TREATMENT	AV. NO. GALLERIES PER SQ. FT. BARK				AV. NO. HOLES PER SQ. FT. WOOD SURFACE				
	DRYO.	DENDRO.	T. CINN.	EVOD.	T. BIV.	G. MAT.	T. CINN.	MONOCHA.	
0.1% Endrin emul.	17.8	0.0	0.0	0.0	5.8	0.0	0.7	1.0	
0.1% Isodrin emul.	25.7	0.0	0.0	0.0	23.8	0.0	0.8	0.0	
6% DDT emul.	2.7	0.0	0.0	0.0	6.2	0.0	0.0	0.0	
6% DDT in oil	5.2	0.0	0.2	0.0	23.8	0.0	0.0	0.0	
12% DDT in oil	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
1.25% lindane in oil	1.3	0.0	0.0	0.0	0.6	5.5	0.0	0.2	
Untreated check	34.6	0.2	1.2	1.7	5.8	0.0	9.5	0.0	

Abbreviated names used in tables:

Bark beetles

Dryo.—*Dryocoetes piceae* Hopk.

Dendro.—*Dendroctonus piceaperda* Hopk.

Borers

T. cinn.—*Tetropium cinnamopterum* Kby.

Evod.—*Evodinus* sp. (probably *monticola* Rand.)

Monocha.—*Monochamus scutellatus* Say

Ambrosia beetles

T. biv.—*Trypodendron bivittatum* Kby.

G. mat.—*Gnathotrichus materiarius* Fitch

larvae which may have been killed by the chemical, but since only one log had been treated, the results were not conclusive.

A preliminary examination of the uninfested logs was made on the same day. Examination of $\frac{1}{4}$ square foot bark samples indicated that none of the treated logs had been attacked. Untreated logs showed attack by *Dryocoetes piceae* and one log had a *Dendroctonus piceaperda* (eastern spruce beetle) gallery with its complement of eggs. Bark on all the logs was still green.

Final examination of the uninfested logs series was made on October 20, 1953. Two 1-square-foot bark samples were removed from each log from locations near each end, and counts were made of the insect entries into the bark and wood. The counts from the 3 replicate logs in each treatment were averaged. Average small-end diameter of the logs was 10.5 inches. A summary of the data appears in table 4. The 12 percent DDT treatment gave the best protection over 15 months of test and allowed the least number of insect entries. The entries which were found were made by the bark beetle *Dryocoetes piceae*. Since they were made during the late summer of 1953, it was indicated that complete protection for at least a year had been obtained. Bark on the treated logs was still green and appeared almost as fresh as the day the logs were cut. The 6 percent DDT did not give as good protection as 12 percent DDT although the bark on the logs was still fairly green and apparently was not attacked until the summer of 1953. There was no borer attack in the wood in any of the DDT treatments.

Lindane appeared to give as good protection against bark beetle entry as 12 percent DDT, but allowed entry by ambrosia beetles and borers. The bark of the lindane-treated logs was partly brown, tight and beginning to dry. Bark beetle larvae found in it had died before they reached maturity, presumably as the result of the log treatment. In this respect lindane may have an advantage over DDT, which seemed to have no effect either on the bark itself or on the insects in or under the bark.

The endrin and isodrin, at recommended concentrations, allowed a larger number of insect entries, and the treatments were therefore considered to be inferior to DDT and lindane. Bark on logs sprayed with endrin and isodrin was brown and rotting. Live beetles were still present in the bark at the time of examination and emergence of adults had already taken place. Most of the beetles in the check logs had emerged although there were still a few borer larvae under the bark which by that time was brown and rotting.

Although the bark in the 12 percent DDT treatment was still green and capable of breeding bark beetles and borers a year after the logs

were treated, the fact that good protection was given the logs for a year would seem to warrant further study of treatment for use in logging operations, especially where logs may be kept a year before processing. Storage of logs for more than one year would be unusual.

Spraying with a portable hand sprayer such as was used in these tests appears to be an easy way to protect green logs as they are cut in the woods, provided treatment is applied before attack occurs. Since complete spray coverage is necessary to assure good protection, it can best be done at this time, while the bark on the logs is still clean. Soil caked on skidded logs would interfere with good spray coverage. Since spraying in the woods is not always feasible, it may be easier to skid the logs out to the skidway and spray them there. It would then be advisable to sweep off any soil from the logs before treatment. This can be done when the logs are turned to be sprayed.

It is of utmost importance that the logs be treated as soon as possible after they are cut if maximum protection is to be obtained. The logs should be dry as well as clean before spraying and the spray should be applied to the runoff point. Logs can be decked immediately after spraying.

Recommended precautions for the use of DDT in oil should be observed by the spray operators and those handling sprayed logs. Operators should have on hand soap and water for frequent washing of the hands and a change of clothing in case spray on clothing comes in contact with the skin.

The protection of untreated logs which must be stored for several weeks or more before milling presents a problem unless such logs can be stored in water. However, this is not always possible.

A mill in Poland, N. Y. installed a water sprinkling system in the summer of 1953 to keep decked yellow birch logs wet and prevent their spoilage from dry rot. Since the treatment appeared to have possibilities in the prevention of insect attack, observations were made on two newly formed log decks, each containing about 400 logs. The logs were kept wet by the continuous operation of sprinklers mounted on top of the deck (figure 23). A third log deck which contained 161 logs and was not sprinkled, was used as the check.

The logs which were examined averaged 14 to 15 inches in diameter and 10 to 12 feet long. Bark samples 1 square foot in size were taken from sample logs in each deck June 24 to July 3, 1953, to determine what insects had attacked prior to treatment. The two treated decks were designated as Deck A and Deck B. In Deck A, the bark samples were only from log surfaces exposed to the outside, which were sprinkled directly. In Deck B, inside logs as well as outside logs were

sampled. In each case, three bark samples were taken from each log (from center and near each end) except from internal logs in Deck A. These logs were sampled only near the ends. The bark on most of the logs was green or partly green at the time of examination.

Counts of beetles and beetle entries showed that *Xylotrechus colonus* F., the rustic borer, attacked the check logs more than the sprinkled logs (table 5). Adults of this species were collected from the log decks at the beginning of the experiment the last week in June, when they appeared to be ovipositing. The larvae were numerous under the bark when the final examinations were made the latter part of August. There appeared to be no difference between the treated and the check logs with respect to populations of other species of beetles found under the bark.

A summary of the counts made in the logs is presented in table 5.

TABLE 5

Summary of results with water sprinkling as a means of protecting decked yellow birch logs from insect attack

						AV. NO. HOLES PER SQ. FT.	
	SQ. FT. BARK	AV. NO. GALLERIES PER SQ. FT.				AMBROSIA*	
DECK	EXAMINED	X. COL.	CHRYSO.	D. BET.	A. ANX.	BETLES	BORER
<i>Pretreatment data</i>							
A	60	.00	.00	.03	.03	1.90	.00
B	144	.11	.15	.01	.06	1.20	.10
Check	72	.33	.00	.12	.35	3.40	.20
<i>Post-treatment data</i>							
A	30	.23	.30	.06	.16	.07	.00
B	30	.30	.00	.00	.10	.30	.03
Check	30	2.76	.07	.07	.40	.80	.00

* Mostly *Xyloterinus politus* with some *Monarthrum mali*.

Abbreviated names used in table

X. col. = *Xylotrechus colonus* F. (cerambycid borer)

A. anx. = *Agrilus anxius* Gory (buprestid borer)

Chryso. = *Chrysobothris* sp. (buprestid borer)

D. bet. = *Dryocoetes betulae* Hopk. (bark beetle)

SUMMARY

This report describes (1) observations on the activities of wood-boring insects and the extent of their attack as affecting salvability of blowdown timber; (2) mill studies of salvaged timber to evaluate the insect damage in the cut lumber and correlate it with the data from

superficial observations; (3) studies in the control of the insects which attack the logs.

Insect attack on down timber was primarily by ambrosia beetles (Scolytidae) and round-headed borers (Cerambycidae). The principal species which attacked softwoods were the ambrosia beetles *Trypodendron bivittatum* and *Gnathotrichus materiarius*, and the borers *Tetropium cinnamopterum* and two species of *Monochamus*. Except for the latter, which penetrated 4 to 7 inches into the wood, most penetration was 2 to 3 inches. The hardwoods were attacked by the ambrosia beetles *Xyloterinus politus* and *Monarthrum mali*. Attack by the former was more serious and penetrated the wood generally to 3 inches but was often found at a depth of 4 to 5 inches. There was some borer attack but most of it was inconsequential.

Mill studies of cut lumber from 47 salvaged red spruce logs showed a direct correlation between insect entry counts on log surfaces and the amount of damage occurring in the cut lumber. Results showed that the greater the intensity of attack the greater the damaged volume by both ambrosia beetles and borers. The data also indicated that fewer borers than ambrosia beetles were required to damage a given volume of wood.

Comparison of mill study data on various tree species involved in the blowdown indicated that the differences in relationship between entries and damaged volume are sufficient among the tree species to make it misleading to attempt to predict from data on red spruce what could be expected in the other species. Also, the following factors appear to be important in determining how much cut volume from a log may be expected to contain insect damage and to what extent: (1) the species of insect attacking; (2) the intensity of insect attack; (3) the diameter of the log; (4) the technique used in cutting the log into lumber. It is therefore important for log graders and scalers to become familiar with the insects and damage occurring in a given logging area and the depths in the wood at which the damage is found. Damage can be culled or logs graded on the basis of type of damage, intensity of attack and the rules regarding exterior defects.

Log spray experiments indicated that it is easier to prevent insect attack than to kill the insects after they have entered. Of the insecticide formulations tested, 12 percent DDT in kerosene applied by hand sprayer as a full coverage spray to uninfested logs prevented insect attack for more than a year.

In a mill yard where decks of yellow birch logs were kept wet by a water sprinkler to prevent dry rot, there was less attack by the round-headed borer, *Xylotrechus colonus*, on the sprinkled logs than on logs not sprinkled.

ACKNOWLEDGMENTS

The following sawmills participated in the mill studies reported in this bulletin: Austin Sawmill, Long Lake; Hutchins Sawmill, Indian Lake; Jamestown Veneer and Plywood Corporation, Poland; Murphy Sawmill, Long Lake; Northern Lumber Co., Poland, and Towsley Sawmill, Newcomb.

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FIGURES 3-8

Figure 3. *Tetropium cinnamopterum* adult (from Felt)

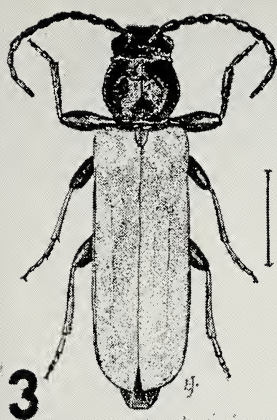
Figure 4. Cerambycid larva (X 1½) (*Monochamus scutellatus*). Drawing by R. K. Bennett

Figure 5. *Polygraphus rufipennis* adult. Drawing by R. K. Bennett, after Craighead (from Swaine)

Figure 6. *Polygraphus rufipennis* gallery on inner bark surface. Drawing by R. K. Bennett

Figure 7. *Monarthrum mali* gallery (from Felt after Hubbard)

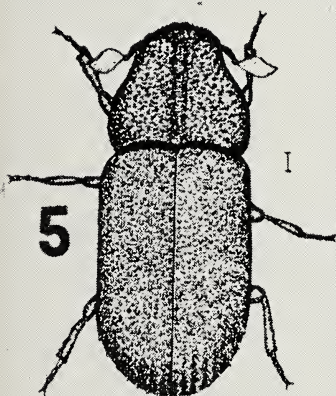
Figure 8. *Monarthrum mali* adult (from Felt after Hubbard)



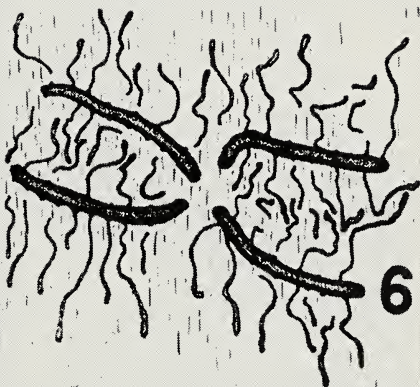
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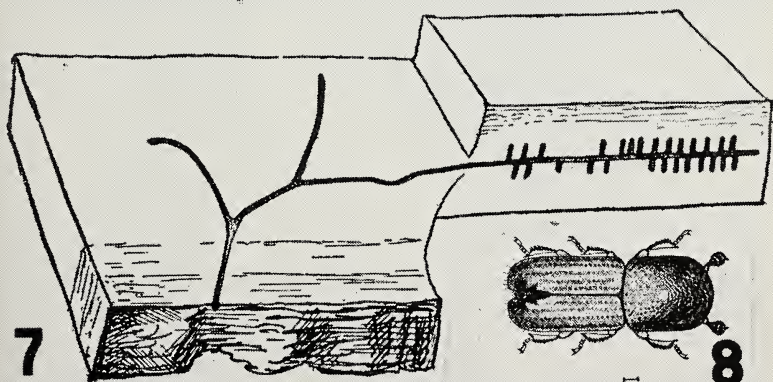
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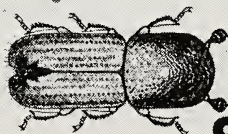
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Figure 9. *Gnathotrichus materiarius* adult (from Felt after Hubbard)

Figure 10. *Gnathotrichus materiarius* gallery. Drawing by R. K. Bennett

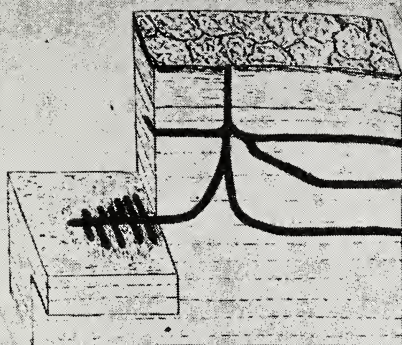
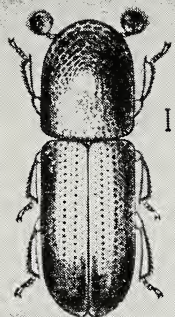
Figure 11. *Xyloterinus politus* adult (from Felt after Hubbard)

Figure 12. *Xyloterinus politus* gallery. Drawing by R. K. Bennett

Figure 13. *Trypodendron bivittatum* adult (from Felt after Hubbard)

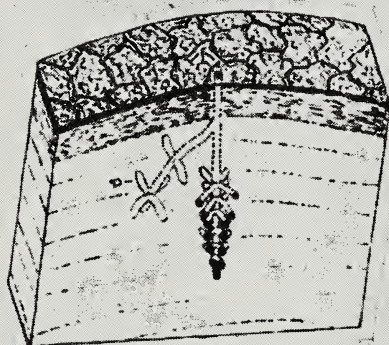
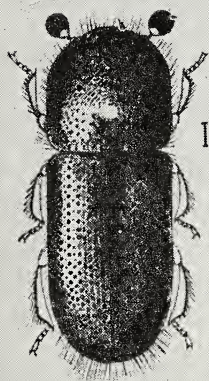
Figure 14. *Trypodendron bivittatum* gallery. Drawing by R. K. Bennett

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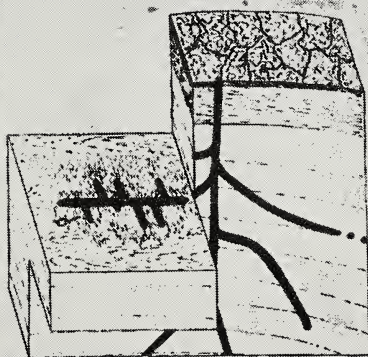
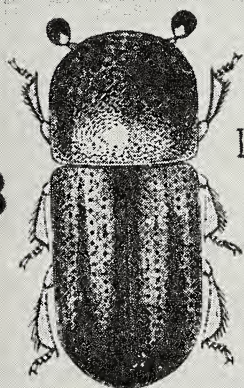
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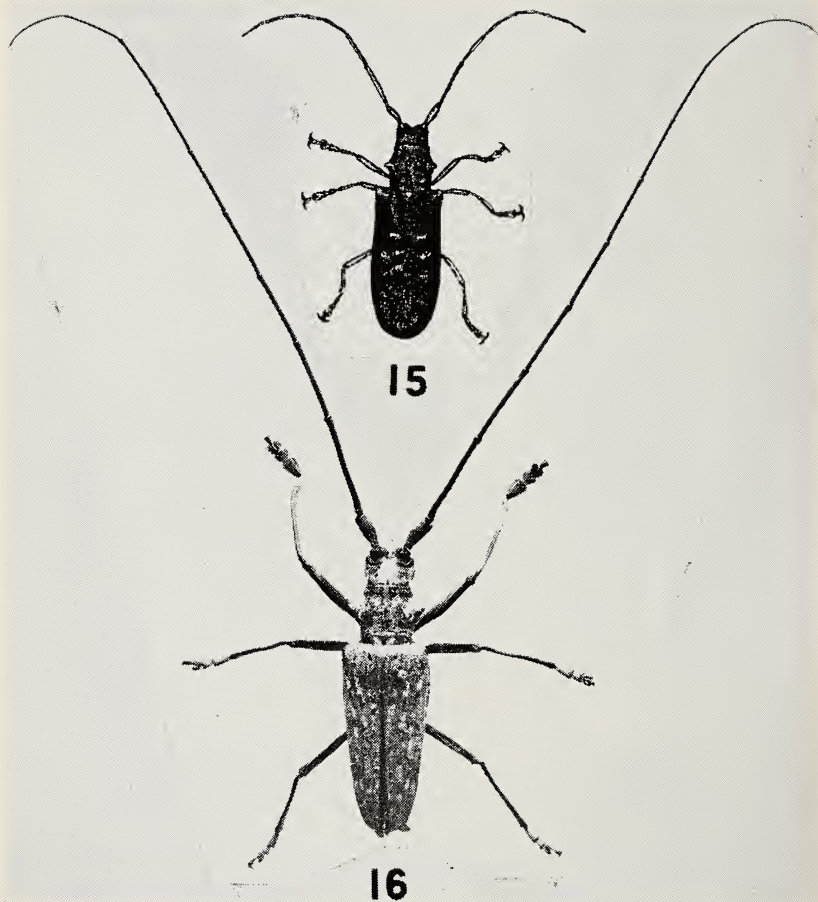


Figure 15. *Monochamus scutellatus* adult female $\times V1\frac{1}{2}$ (from drawing by R. K. Bennett).

Figure 16. *Monochamus notatus* adult male $\times V1\frac{1}{2}$.

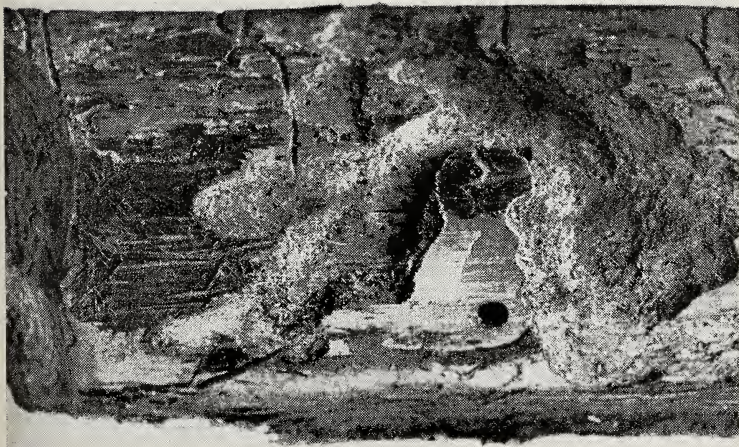


Figure 17. Bark removed from portion of white pine log to show larval tunnel of *Monochamus* sp. (probably *notatus*) on wood surface, and emergence hole of adult.

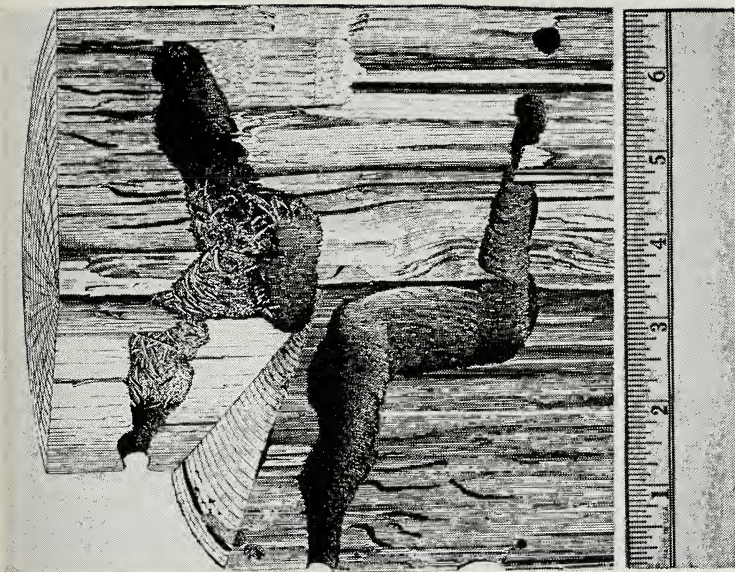


Figure 18. Section of white pine log to show *Monochamus notatus* borings in the interior. Lower boring is larval tunnel showing entrance hole. Upper boring is larval tunnel with frass plug, pupal chamber and emergence hole of adult.

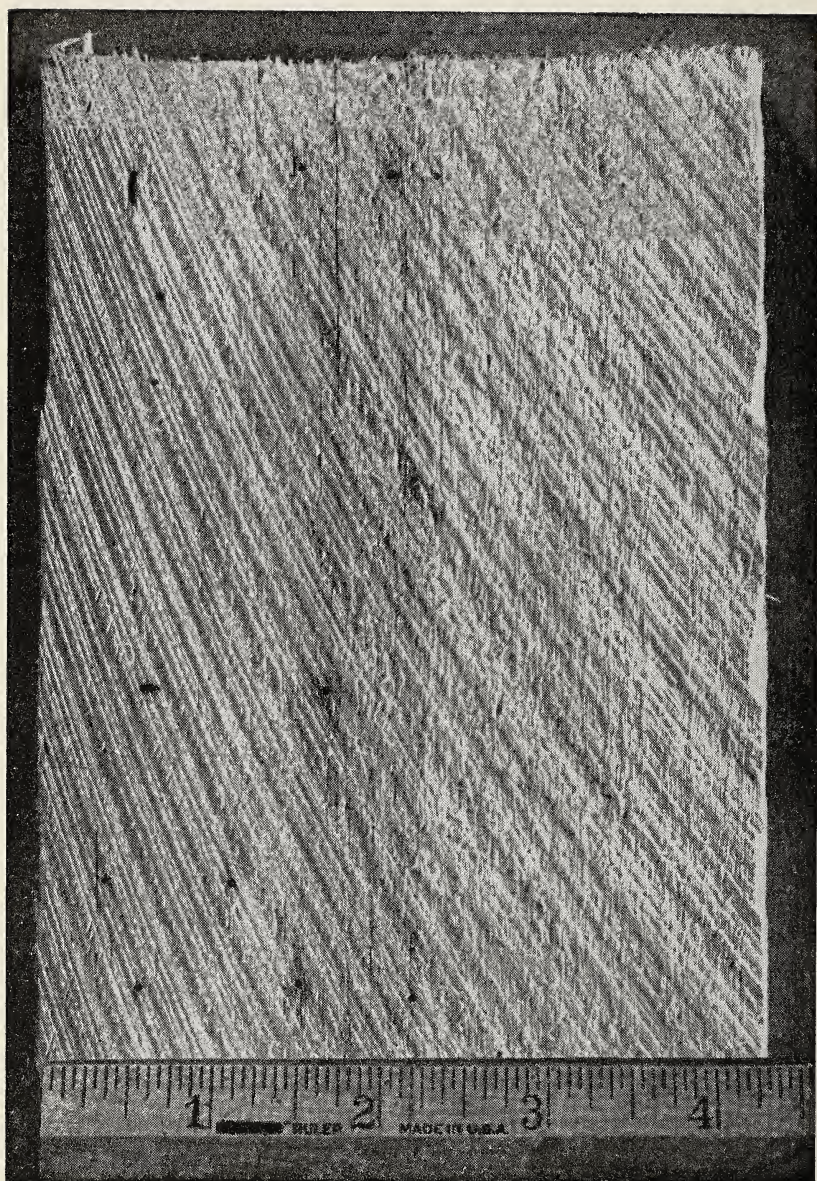


Figure 19. Damage by ambrosia beetle, *Gnathotrichus materiarius*, to white pine.

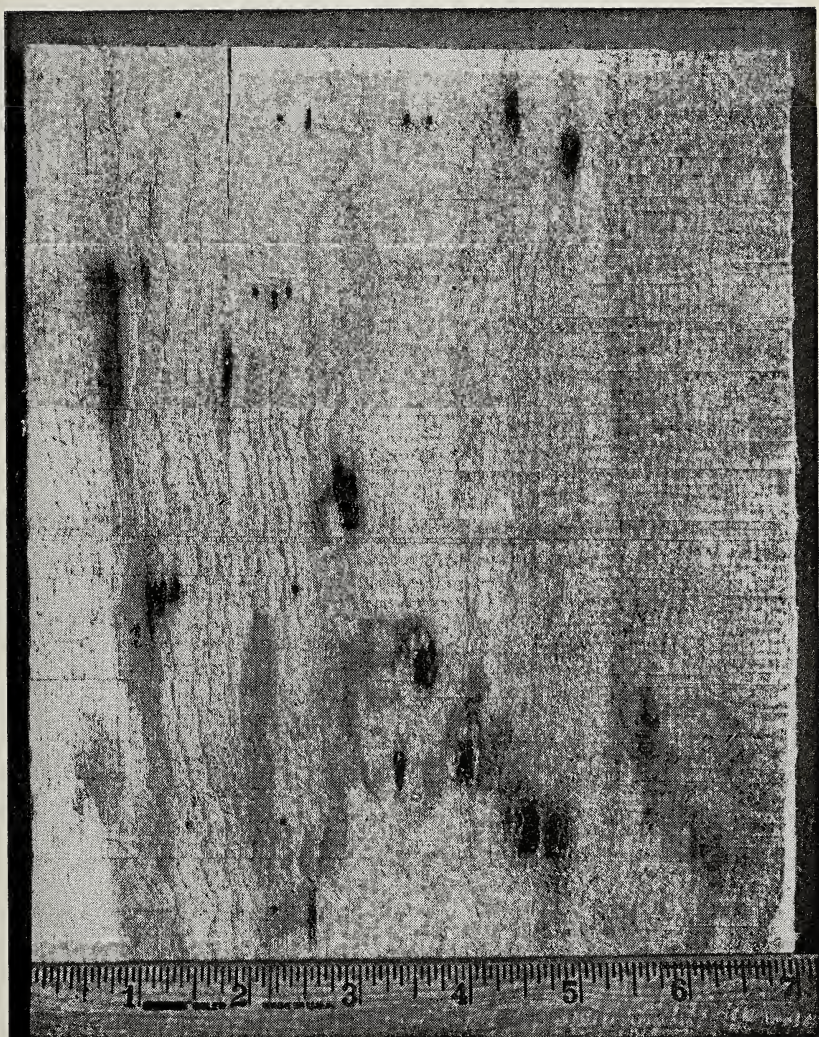


Figure 20. Damage by ambrosia beetle, *Xyloterinus politus*, to yellow birch.



Figure 21. Damage to red spruce by (1) borer, *Tetropium cinnamopterum*, (2) ambrosia beetle, *Trypodendron bivittatum*.

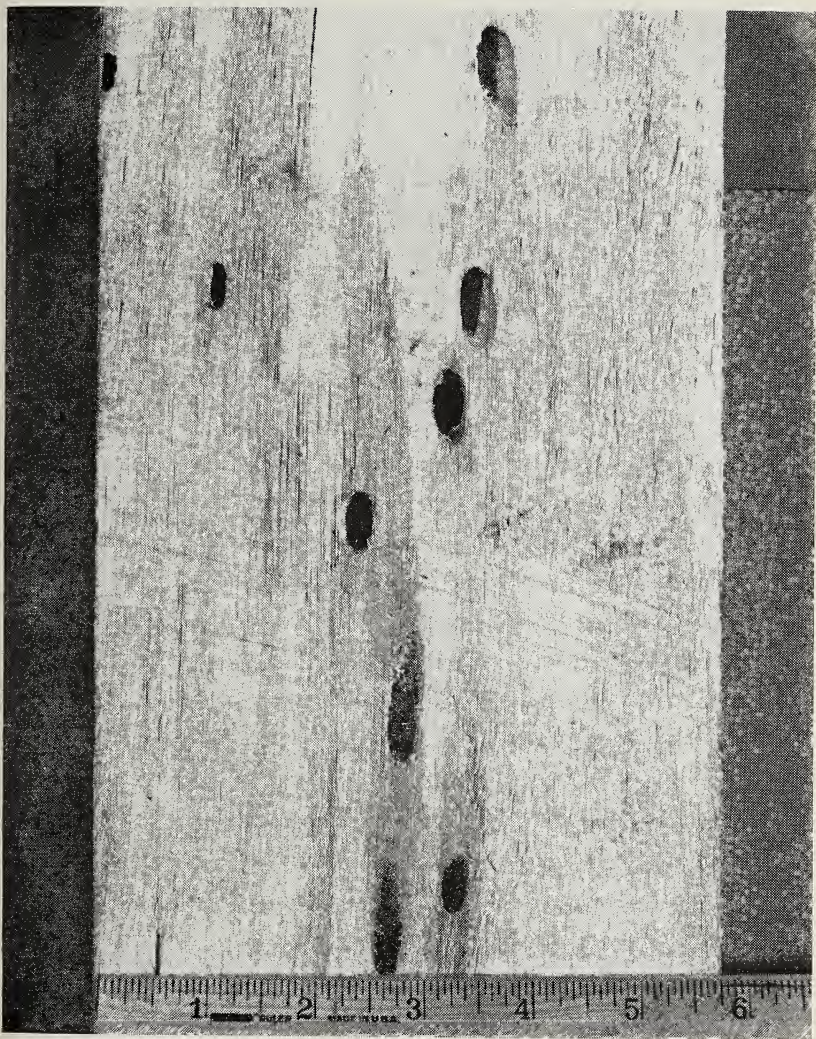


Figure 22. Damage by borer, *Monochamus notatus*, to white pine.



Figure 23, Deked yellow birch logs with sprinkling system mounted on top. Insert is closeup of sprinkler.

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Mammals
and
Siphonapterous Parasites
of
Rensselaer County, New York

By

ALLEN H. BENTON

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MAMMALS AND SIPHONAPTEROUS PARASITES OF RENSSELAER COUNTY, NEW YORK

By

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INTRODUCTION AND ACKNOWLEDGMENTS

From July 13 to September 8, 1953, the senior author collected mammals in Rensselaer County for the New York State Museum and Science Service. Several hundred fleas were taken from the mammals collected, and these specimens were mounted and identified by the junior author. From September 15, 1953, to June 1, 1954, the junior author and Thomas Atkinson collected additional specimens, mostly Lagomorpha and their parasites. The specimens thus collected form the basis for this paper. All specimens are deposited in the collection of the New York State Museum and Science Service, and of the State University College for Teachers, Albany.

The authors are grateful to Thomas Atkinson, Edward Cummings and Roswell Eldridge for assistance in field work; to Major John M. Geary, U. S. Air Force, G. P. Holland, Canada Department of Agriculture, and G. H. E. Hopkins, British Museum (Natural History), for advice and assistance with regard to certain taxonomic problems in the Siphonaptera. Ralph S. Palmer, New York State Museum and Science Service, has given aid and guidance in the preparation of the manuscript, and E. M. Reilly, Jr. assisted in the preparation of the maps.

DESCRIPTION OF AREA

Rensselaer County is one of the eastern tier of counties of New York (figure 1), lying entirely to the east of the Hudson River opposite

¹ Temporary expert, New York State Museum and Science Service, Summer of 1953.

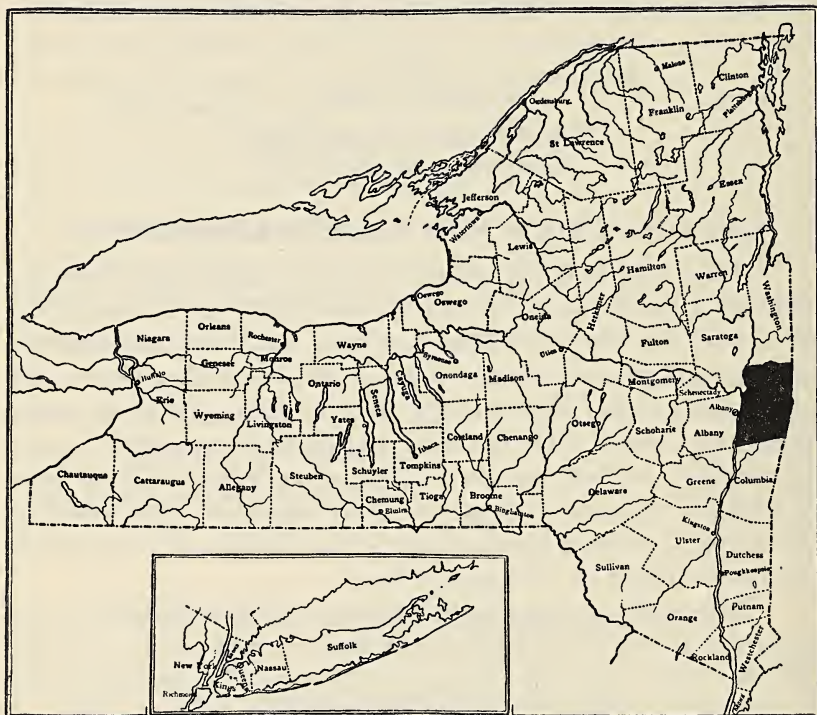


Figure 1. Map of New York State showing location of Rensselaer County, indicated by black area.



Figure 2. Map of Rensselaer County showing town lines. Collecting areas are indicated by dots.

Albany and Saratoga Counties. It includes 651 square miles of widely varying physiographic features, extending from the Hudson River on the west, where the elevation is from 20 to 60 feet above sea level, to a height of nearly 3,000 feet at the peak of the highest of the Taconic Mountains along the eastern border of the county (figure 2).

The narrow flood plain of the Hudson River is occupied by the cities of Rensselaer and Troy and by numerous industrial developments over much of its length. From this plain, the land slopes upward toward the east, sharply in some places and gradually in others, and then extends as a rolling lowland to the foot of the Rensselaer Plateau and the Taconic Mountains. In this lowland area a few isolated monadnocks occur, the highest being Mount Rafinesque (Bald Mountain) in the town of Brunswick, which reaches 1,197 feet.

This lowland area shows definite southern affinities in its flora and fauna, lying within the Upper Austral zone of Merriam *et al.* (1910). The forest trees are largely deciduous, except for white pine, *Pinus strobus*, and in some sandy areas pitch pine, *Pinus rigida*. In this area most of the land is farmed, dairying being the chief type of agriculture.

From the lowland, the Rensselaer Plateau rises in the center of the county, extending for some 20 miles from north to south. The top of the plateau is rough and generally rolling, reaching heights of nearly 2,000 feet. Numerous small lakes and ponds and swampy areas of varying size dot the top of the plateau (figure 6). To both east and west the plateau slopes off rather sharply, although in only a few places are the slopes rocky and precipitous.

To the east of the Rensselaer Plateau, a deep valley separates it from the higher and more rugged Taconic Mountains, which lie along the entire eastern edge of the county. The valley broadens out at the north into the Hoosick Valley, and at the south into the Stephentown Valley. Ridges from the Taconic Mountains extend to the westward into these valleys for one to four miles in several places (Latimer *et al.*, 1937).

The original vegetation of the county consisted mainly of oak-chestnut-hickory forests in the lowlands and maple-hemlock-birch forests at the higher elevations, with poorly drained swamps covered with red spruce, *Picea rubens*, and balsam fir, *Abies balsamea*, on the Rensselaer Plateau. Little semblance of the original condition remains today. The Rensselaer Plateau in particular has been persistently lumbered and now consists largely of second growth, with extensive areas covered by gray birch, *Betula populifolia*, and poplar, *Populus* sp. Cleared land is in many instances abandoned and, even where pastures

and hayfields are still used, the hardhack, *Spiraea tomentosa*, and meadow sweet, *Spiraea latifolia*, are constantly encroaching.

The varied topography and vegetation provide suitable habitat for numerous species of mammals. Although no bats and few furbearers or game mammals were collected during this survey, 25 species of mammals were taken. This represents about half of the mammals known to exist within the county. From these mammals, 19 species of fleas were taken (table 1), and this represents about half of the fleas which Geary (1954) reported from eastern New York.

The host distribution of these fleas is indicated in table 1. It will be noted that some species of mammals harbored no fleas, while others served as host to several species. Similarly, many of the flea species are exceedingly host-specific, while others may be found on several mammalian orders. The available information concerning host distribution is summarized under the account of each species in the following pages.

DISCUSSION OF SPECIMENS COLLECTED

Sorex c. cinereus Common shrew

Specimens collected: 2

Fleas removed: None

Sorex f. fumeus Smoky shrew

Specimens collected: 3

Fleas removed: None

Sorex palustris albibarbis Northern water shrew

Specimens collected: 1

Fleas removed: None

Only one flea which occurs in this area, *Corrodopsylla c. curvata* (Rothschild), appears to infest shrews of the genus *Sorex* regularly. The one specimen of this species taken during this survey was on a big short-tailed shrew, *Blarina brevicauda*, but *Sorex* is more probably the typical host.

Blarina brevicauda talpoides Big short-tailed shrew

Specimens collected: 89

Fleas removed: *Doratomyia blarinae* (C. Fox)—41

Ctenophthalmus p. pseudagyrtes (Baker)—29

Corrodopsylla c. curvata (Rothschild)—1

Ctenocephalides f. felis (Bouche)—1

The 15 subspecies of the big short-tailed shrew listed by Miller and Kellogg (1955: pp. 34-37) include several poorly marked forms

This species has no typical flea parasites locally. A louse, *Trichodectes mephitidis* (Pack.), was removed from this specimen.

Tamias striatus Eastern chipmunk

Specimens collected: 8

Fleas removed: *Tamioiphila grandis* (Rothschild)—1

Megabothris acerbus (Jordan)—1

Miller and Kellogg (1955: p. 218) include Rensselaer County within the range of *Tamias striatus lysteri*. Some specimens, however, tend toward *T. s. fisheri*, which occurs in the lower Hudson Valley. Pending critical examination of a large series, it seems best to leave the subspecific determination of these specimens in question.

Both species of fleas taken from the chipmunk are host-specific for this mammal, and both are comparatively scarce in collections.

Sciurus carolinensis leucotis Eastern gray squirrel

Specimens taken: 1

Fleas removed: *Orchopeas h. howardii* (Baker)—6

The gray squirrel is the true host of this common flea, which occurs in great numbers both on the squirrels and in their nests. Within the range of the gray squirrel it often occurs on other hosts, and this fact, coupled with the poorly marked differences among females of the genus *Orchopeas*, leads to great difficulty in identification. The presence or absence of a complete row of frontal bristles has been used to separate the squirrel-infesting group (*O. howardii* and *O. caedens* in the East) from the mouse-infesting group (*O. leucopus* and *O. sexdentatus* in this region). Cummings (1954), however, concluded that this characteristic is not completely reliable, and the outline of Sternite VII, which is the other taxonomic character used in determining females of these species, is so variable as to be of little value in individual cases. It would seem wise in questionable cases to leave the identity of the specimen incomplete, rather than to compound the present confusion about the distribution of certain of these species (see discussion under the red squirrel).

Tamiasciurus hudsonicus loquax Red squirrel

Specimens taken: 2

Fleas removed: *Monopsyllus vison* (Baker)—2

Orchopeas h. howardii (Baker)—1

The geographical distribution of the siphonapterous parasites of red squirrels in the East presents an interesting problem. Two species of fleas are host-specific for this squirrel: *Monopsyllus vison* (Baker) and *Orchopeas caedens durus* (Jordan). The former appears to occur

throughout New York State, wherever the red squirrel is found. The latter is common in the Adirondacks, but throughout the rest of the State it is largely replaced by *O. h. howardii*, which is a true parasite of the gray squirrel, and, as remarked by Holland (1947), does not appear to be able to exist beyond the range of that mammal. Within that range, however, it occurs on a variety of other mammals, mostly Sciuridae. Although Geary (1954, MS) lists several records of *O. howardii* from Essex County, and one record of *O. caedens* from Ithaca, Layne (1954) found no *O. caedens* among 622 fleas from red squirrels in the Ithaca region. Since the unlikely records which Geary cited are based on females, which are notoriously variable in the genus *Orchopeas*, there is a strong possibility that they are based on erroneous identifications. The Adirondack specimens, in particular, were from deer mice, *Peromyscus* sp., and were in all probability *O. leucopus*.

It might be expected that *O. caedens* would occur in the higher areas of the Catskill Mountains, but specimens from this area have not been available to us. Extensive collections from all parts of the State are needed before the details of the distribution of these species can be completely understood.

Epitedia faceta (Rothschild) is also a parasite of the red squirrel in this area, but this species appears to be rather rare. It was not collected during this survey.

Glaucomys sabrinus macrotis Northern flying squirrel

Specimens taken: 1

Fleas removed: *Opisodasys pseudarctomys* (Baker)—1

The flying squirrels, both this species and *G. volans*, are the typical hosts of this flea.

Peromyscus maniculatus gracilis Common deer mouse

Specimens taken: 33

Fleas removed: *Orchopeas leucopus* (Baker)—17

Peromyscopsylla h. hesperomys (Baker)—2

Ctenophthalmus p. pseudagyrtis (Baker)—1

Peromyscus leucopus noveboracensis Woodland deer mouse

Specimens taken: 124

Fleas removed: *Orchopeas leucopus* (Baker)—55

Peromyscopsylla h. hesperomys (Baker)—24

Ctenophthalmus p. pseudagyrtis (Baker)—2

Epitedia wenmanni testor (Rothschild)—1

Megabothris quirini (Rothschild)—1

The two species of *Peromyscus* occur together at elevations above 1,000 feet throughout the county, with *P. maniculatus* becoming more common above 2,000 feet. In areas where both occur, occasional individuals are extremely difficult to identify with certainty. Field identification depends upon the relatively longer tail of *P. maniculatus*, which is thicker at the base and more sharply bicolor than that of *P. leucopus*. These characteristics are relative and an occasional individual will not show the distinctions clearly. If the eyes are removed from the skull, it will be found that the eye of *P. maniculatus* is much smaller than that of *P. leucopus*. This too, however, is a comparative characteristic which is not distinguishable externally. The final test of identification is the skull, several minor characters of which differ in the two species.

The two species share the same flea fauna, and both are relatively heavily parasitized. The host-flea indices of the two are: *P. leucopus*, .66; *P. maniculatus*, .60; *Orchopeas leucopus*, *Peromyscosylla hesperomys*, and *Epitedia wenmanni testor* are all typical parasites of *Peromyscus*.

Epitedia wenmanni testor was described as a full species by Rothschild (1915) on the basis of a female taken from a mouse nest at Lansingburg, a suburb of Troy in Rensselaer County. Until 1954, no flea student had attempted to evaluate the validity of the species. During previous flea studies, the senior author had noted minor differences between *E. wenmanni* from the Hudson Valley and those from northern New York. After the specimen listed above was taken, the authors recognized its importance as the only male from the type locality of *E. testor*. Correspondence with G. H. E. Hopkins of the British Museum (Natural History), where the type specimen is kept, revealed that he had already reached a tentative conclusion as to the identity of *E. testor*, having established some taxonomic characteristics which he felt were significant. We therefore sent him our specimens from this area, and the male topotype was designated by him as neallotype. He described the male for the first time (Hopkins, 1954), and reduced the form to subspecific status. The distribution of the two subspecies has been outlined by the senior author (Benton, 1955).

Synaptomys c. cooperi

Cooper's lemming mouse

Specimens collected: 1

Fleas removed: *Ctenophthalmus p. pseudagyrtes* (Baker)—1

The lemming mouse has no host-specific fleas in this region, so far as is known. It is so seldom taken that little is known about its parasites. The single specimen taken was collected on the west slope

of Berlin Mountain¹, in second-growth forest at an elevation of about 1,600 feet. It was taken in a runway in the leaf mold, at the point shown in figure 3.

Clethrionomys gapperi

Northern red-backed mouse

Specimens collected: 93

Fleas removed: *Peromyscopsylla catatina* (Jordan)—13

Megabothris quirini (Rothschild)—8

Ctenophthalmus p. pseudagyrtes (Baker)—8

Orchopeas leucopus (Baker)—2

Orchopeas sp.—1

Peromyscopsylla h. hesperomys (Baker)—1

The taxonomy of the red-backed mice taken during this survey is as yet uncertain. Two distinctly different populations exist, the one occupying the higher levels of the Rensselaer Plateau, from about 1,300 feet to the top, the other occurring elsewhere throughout the county at elevations higher than about 900 feet. The Rensselaer Plateau population is made up of large brightly colored specimens, averaging (adults only, as determined by sexual maturity) 147 mm. in total length, (132-162 mm., 20 individuals included). The weight of 17 adults, including no pregnant females, averaged 29.6 grams (21.1-38.4). These specimens appear to resemble *C. g. ochraceus* in size and coloration. In contrast, 22 adults from other areas averaged 135.2 mm. (125-144) in total length, and 21 of these averaged 23.7 grams in weight (20.0-28.0 gms.). Four individuals from the eastern slope of the Rensselaer Plateau are averaged separately, because they appear to belong to the smaller form. These four averaged 132.5 mm. in length (125-137) and 23.5 grams in weight (22.6-24.5 gms.), although the locality was near the top of the Rensselaer Plateau and close to several areas where the larger form was taken.

These differences may be environmental rather than genetic, but the two forms are strikingly different when collected. A large female from Dutch Church, town of Berlin, which measured 162 mm. in length and weighed 38.4 gms. exceeded the largest specimen taken from any point off the plateau by 12 percent in length and 30 percent in weight.

¹ There is much confusion on maps as to the identity of Berlin Mountain. The Soil Survey of Rensselaer County, (Latimer *et al.*, 1937), in common with most older maps, designates the high point of the Rensselaer Plateau, between Taborton and Center Berlin, as Berlin Mountain. The Berlin Mountain Fish and Game Club has its headquarters here and most local residents apparently think of this area as Berlin Mountain. The United States Geological Survey, on the Berlin Quadrangle, Edition of 1948, gives this name to the 2,800-foot peak lying on the New York-Massachusetts border, directly east of the village of Berlin. On some of the older maps, this peak is called Macomber Mountain.

In this paper, usage follows the most recent U. S. G. S. map, designating the peak east of Berlin, the highest point in Rensselaer County, as Berlin Mountain.



Figure 3. Northwest slope of Berlin Mountain, Town of Berlin, looking downward from elevation 1,700 feet. Trapline at left of trail took: *Synaptomys c. cooperi*, *Pitymys pinetorum scalopsoides*, *Clethrionomys gapperi*, *Peromyscus maniculatus gracilis*, *Napeozapus i. insignis*, and *Tamias striatus*.



Figure 4. Rocky hillside two miles northeast of Poestenkill, Town of Poestenkill, near Davitt Pond at elevation 1,300 feet. Trapline in this area took: *Sorex f. fumus*, *Blarina brevicauda talpoides*, *Glaucomys sabrinus macrotis*, *Peromyscus leucopus noveboracensis*, *P. maniculatus gracilis*, *Pitymys pinetorum scalopsoides*, and *Clethrionomys gapperi*.



Figure 5. Poesten Kill two miles east of Barberville, Town of Poestenkill, at elevation 900 feet. Trapline along creek and in field to left took: *Blarina brevicauda talpoides*, *Tamias striatus*, and *Peromyscus leucopus noveboracensis*.



Figure 6. Boggy sedge meadow one mile south of Dutch Church, Town of Berlin at elevation 1,720 feet. Trapline in this meadow took: *Microtus p. pennsylvanicus*, *Zapus h. hudsonius* and *Napcozapus i. insignis*.

Both *Megabothris quirini* and *Peromyscopsylla catatina* are host-specific for the red-backed mouse. Although both are occasionally taken on other mammals, their distribution is definitely controlled, in this region, by the distribution of this mammal. *P. catatina* seems to be replaced in the west by *P. selenis*, which is also typically found on *Clethrionomys*, while *M. quirini* occurs across the northern part of the continent (Holland, 1947).

The unidentified specimen of *Orchopeas* was a female from Petersburg, which could not be identified with certainty. (See discussion of genus *Orchopeas* under gray squirrel.)

Microtus p. pennsylvanicus Meadow vole

Specimens collected: 26

Fleas removed: *Ctenophthalmus p. pseudagyrtes* (Baker)—8

Megabothris a. asio (Baker)—2

Peromyscopsylla catatina (Jordan)—1

Of the three species of fleas recorded from this mammal, only *Megabothris a. asio* is largely restricted to it. The fact that this appears to be a nest-flea may account for its relative rarity.

Pitymys pinetorum scalopsoides Pine mouse

Specimens collected: 2

Fleas removed: *Ctenophthalmus p. pseudagyrtes* (Baker)—6

The pine mouse has no host-specific fleas in this area, but

Ctenophthalmus p. pseudagyrtes is often found upon this mammal.

Rattus norvegicus Brown rat

Specimens collected: 2

Fleas removed: *Nosopsyllus fasciatus* (Bosc)—1

Sturm (1955, MS) has shown that *Nosopsyllus fasciatus* is the only flea which is commonly found on rats in this area. Both *Xenopsylla cheopis* (Rothschild) and *Echidnophaga gallinacea* (Westwood) have been taken from rats in New York, but intensive collecting by Sturm in Albany County yielded no specimens of either of these species.

Mus musculus domesticus House mouse

Specimens collected: 3

Fleas removed: None

Only one flea, *Leptopsylla segnis* (Schönherr) is often found on the house mouse in the United States, and this species appears to be very rare in New York.

Zapus h. hudsonius Meadow jumping mouse

Specimens collected: 12

Fleas removed: None

Napeozapus i. insignis Woodland jumping mouse

Specimens collected: 14

Fleas removed: *Ctenophthalmus p. pseudagyrtes* (Baker)—1

Megabothris quirini (Rothschild)—2

The two species of jumping mice have no host-specific fleas in eastern North America. Holland (1947) listed both *Megabothris quirini* and the western *M. abantis* as true parasites of jumping mice, but the evidence suggests that Microtines are the true hosts of both these species.

Lepus americanus virginianus Varying hare

Specimens collected: 2

Fleas removed: *Cediopsylla simplex* (Baker)—69

Sylvilagus floridanus Eastern cottontail

Specimen collected: 41

Fleas removed: *Cediopsylla simplex* (Baker)—94

Sylvilagus transitionalis New England cottontail

Specimens collected: 9

Fleas removed: *Cediopsylla simplex* (Baker)—124

Atkinson (1954, MS) studied the distribution of the cottontails in Rensselaer County. He found that *S. transitionalis* occurs on the Rensselaer Plateau, while *S. floridanus* occurs throughout most of the rest of the country. No specimens were available from the higher parts of the Taconic Mountains, where *S. transitionalis* might be expected to occur. Range maps in the older works, (e.g., Nelson, 1909) do not include this part of New York State in the range of *S. floridanus*. Three possible sources of the present population are evident. It is known that some shipments of *S. f. alacer* from the midwest were released in the county in recent years. *S. f. mallurus* occurs in the lower Hudson Valley, and is known to have extended its range considerably since Nelson's work (Dalke, 1935), and may well have entered Rensselaer County. *S. f. mearnsi* occurs over much of the rest of New York State, and may have extended its range to the eastward across the Hudson River into Rensselaer County. The present population may well represent a mixture of all three subspecies. In Rensselaer County, it now occurs throughout the lowlands along the Hudson, and in the valley between the plateau and the Taconic Mountains.

SUMMARY

Twenty-five species of small mammals were collected in Rensselaer County during 1953 and 1954. Nineteen species of fleas were found to infest these mammals. Host preferences and ecological distribution are noted for the various species of fleas. Taxonomic and distributional notes on several species of mammals are included.

LIST OF COLLECTING LOCALITIES

Town of Poestenkill

2 miles northeast of Poestenkill village, near Davitt Pond, at elevation 1,300 feet. July 13-18, August 27-29, 1953.

East edge of Poestenkill village, at and near edge of Poesten Kill, at elevation 600 feet. July 13-18, 1953.

$\frac{1}{2}$ mile east of Barberville, on slope of Snake Hill, at elevation 1,000 feet. July 20-23, 1953.

2 miles east of Barberville, along bank of Poesten Kill at elevation 900 feet. July 20-22, 1953.

$2\frac{1}{2}$ miles southeast of Barberville, around grassy swale at 1,182 feet, and along edge of second-growth woodland at 1,200 feet. July 21-23, 1953.

$1\frac{1}{2}$ miles northeast of East Poestenkill, in hemlock-birch-maple forest at elevation 1,350 feet. July 23-25, 1953.

3 miles east of East Poestenkill, in sedge swale at elevation 1,500 feet. July 23-24, 1953.

1 mile east of East Poestenkill, along edge of Poesten Kill at elevation 1,150 feet. July 22-25, 1953.

Town of Berlin

Dutch Church, 4 miles east of Taborton, in second-growth beech-birch-maple woodland at elevation 1,800 feet. July 23-25, 1953.

$\frac{1}{2}$ mile west of Berlin, on steep rocky wooded hillside, at elevation 1,650 feet. July 27-29, 1953.

1 mile south of Berlin, in dry bed of small stream in hemlock forest at elevation 1,300-1,400 feet. July 27-29, 1953.

$1\frac{1}{4}$ miles west of Berlin, in red spruce-white birch-maple woodland near Kendall Pond, at elevation 1,775 feet. July 27-29, 1953.

Dutch Church, 4 miles east of Taborton, in grassy abandoned field at elevation 1,860 feet. July 29-August 1, 1953.

$\frac{1}{2}$ mile southwest of Dutch Church, in swampy hemlock-yellow birch woodland at elevation 1,770 feet. July 29-August 1, 1953.

1 mile south of Dutch Church, in sedge meadow along small stream at elevation 1,720 feet. July 29-August 1, 1953.

1½ miles southeast of Dutch Church, along nearly dry stream bed at woodland edge, at elevation 1,850 feet. August 10-12, 1953.

1½ miles southeast of Dutch Church, in second-growth woodland of beech-birch-maple at elevation 1,850 feet. August 10-12, 1953.

Dutch Church, in spruce-balsam-hemlock forest at elevation 1,850 feet. August 12-15, 1953.

1 mile west of Dutch Church in sedge swale at elevation 1,700 feet. August 12-14, 1953.

½ mile west of Dutch Church in swampy hemlock-spruce forest at elevation 1,750 feet. August 14-15, 1953.

Northwest slope of Berlin Mountain in beech-yellow birch-maple second-growth forest at 1,600-1,700 feet. August 25-27, 1953.

North slope of Berlin Mountain in spruce-paper birch-striped maple forest at 2,300 feet. August 25-27, 1953.

1¼ miles east of Taborton, in spruce-hemlock-maple forest at elevation 1,600 feet. September 3-5, 1953.

2½ miles southwest of Berlin, in sedge-buttonbush marsh at elevation 1,630 feet. September 7-9, 1953.

4 miles southwest of Berlin, near outlet of Dyken Pond, in maple-birch-hemlock forest at elevation 1,600 feet. September 7-9, 1953.

½ mile south of Dutch Church at edge of spruce swamp, at elevation 1,750 feet. January 30-February 6, 1954.

Town of Petersburg

4 miles southeast of Petersburg, in beech-birch-maple forest on White Rocks Hill at elevation 2,250 feet. August 3-5, 1953.

4 miles southeast of Petersburg, in open grassy and shrubby area at top of Jim Smith Hill, at elevation 2,275 feet. August 3-5, 1953.

3¾ miles southeast of Petersburg, along bed of nearly dry stream and in talus rock at elevation 1,750 feet. August 3-5, 1953.

Vicinity of Petersburg, along roads at elevation 700-800 feet. February 9-13, 1954.

Town of Grafton

1½ miles west of Grafton in sedge swale along Route 2 at elevation 1,390 feet. August 6-8, 1953.

Town of Brunswick

4 miles west of Grafton along edge of Quacken Kill at elevation 900 feet. August 6-8, 1953.

Vicinity of Troy Reservoir, 1 mile northwest of Brunswick Center, January 3, 1954.

Mt. Rafinesque, (Bald Mountain), at elevation about 1,000 feet. March 12, 1954.

Town of Sand Lake

$\frac{3}{4}$ mile north of West Stephentown in small growth of beech-birch-maple-ash at 1,300 feet. August 17-20, 1953.

$1\frac{1}{2}$ miles southeast of Sand Lake, in sedges along edge of pond at elevation 825 feet. September 1, 1953.

Southwest shore of Burden Lake. November 27, 1953.

Town of Stephentown

$2\frac{1}{4}$ miles north-northwest of West Stephentown, in beech-birch-maple forest at 1,850 feet. August 17-20, 1953; March 31-April 4, 1954.

$2\frac{1}{2}$ miles north-northeast of West Stephentown, in beech-birch-maple forest at elevation 1,900 feet. August 17-20, 1953.

$1\frac{3}{4}$ miles southeast of West Stephentown along Roaring Brook at elevation 1,350 feet. August 20-22, 1953.

Village of Dunham Hollow in hemlock-beech forest at elevation 1,050 feet. August 20-22, 1953.

Town of Nassau

$\frac{3}{4}$ mile northeast of Hoag Corners in hemlock-beech forest at elevation 800 feet. August 20-22, 1953.

$1\frac{1}{2}$ miles northwest of Hoag Corners in hemlock-beech-birch-maple forest at elevation 700 feet. August 31-September 1, 1953.

1 mile southwest of Hoag Corners in dry sedge swale at elevation 700 feet. August 31-September 1, 1953.

Town of North Greenbush

$3\frac{3}{4}$ miles east of Rensselaer in abandoned field and marsh at elevation 550 feet. September 3-5, 1953.

Snyder's Lake, at elevation 500 feet. February 4, 1954.

Town of Pittstown

Two miles west of Raymertown, at elevation 500 feet. September 21, 1953.

Vicinity of Valley Falls, at elevation 400 feet. November 7 and 21, 1953.

Town of Schaghticoke

3 miles northeast of Melrose at elevation 350 feet. October 25, 1953.

Town of Hoosick

5 miles east of Boyntonville at elevation 800 feet. March 1, 1954.

City of Troy

Lansingburg, in oak woodland. October 1 and 22, 1953; March 5, 1954.

City of Rensselaer

Near railroad yards, at elevation 25-30 feet. August 24-25, 1953.

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PRECAMBRIAN GEOLOGY AND MINERAL RESOURCES OF THE BRIER HILL QUADRANGLE, NEW YORK

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ABSTRACT

The Brier Hill quadrangle is located in northwestern New York, adjacent to the St. Lawrence River. Black Lake, which trends northeast through the area, forms a natural boundary between a highly irregular topography of low relief on Precambrian crystalline rocks to the south-east, and a succession of flat surfaces bounded by scarps on flat-lying lower Paleozoic sedimentary rocks to the northwest.

The whole area has been glaciated. The strike and direction of last effective movement of ice is approximately S. 15° W. Ground moraine, outwash deposits, and lacustrine (Lake Iroquois?) clays occur in the area. The present drainage pattern may have been established to a large extent concomitantly with a glaciation. Three parallel bed-rock channels, which average about 1¼ miles in width and more than 150 feet in depth, are present within a 9-mile-wide belt across the area. The northwesternmost channel is at present occupied by the St. Lawrence River; the other two channels are now partly filled with unconsolidated material upon which minor streams flow. These channels may have been cut and probably were at least enlarged by large streams marginal to one or more of the Pleistocene ice sheets.

Grenville series rocks and various igneous rocks of Precambrian age and early Paleozoic sedimentary rocks crop out in the area. Marble, quartzite, marble tectonic breccia and various gneisses constitute the Grenville series in the Brier Hill quadrangle. Of these, marble tectonic breccia is of greatest areal importance. The structural interpretation of this breccia is one of the major problems encountered. Most evidence apparently supports the idea that major structures can be defined by a statistical analysis of the orientations of minor folds (e.g., folded tectonic breccia fragments).

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Garnet gneiss (locally sillimanite-bearing) and melanocratic foliates that occur as xenoliths in some of the igneous masses also may represent members of the Grenville series. Evidence suggests that the garnet gneiss may represent a reconstituted aluminous sedimentary rock. Apparently the melanocratic gneisses, which comprise many different petrographic types such as amphibolite, pyroxene-plagioclase foliates and intermediate types, many of which contain notable amounts of biotite, had essentially their present petrographic nature even before injection of their hosts.

Biotite granite, quartz syenite gneiss, granitic augen gneiss, trondhjemite, alaskite gneiss, amphibolitized melanocratic dike rock, aplite and basalt are igneous rocks present in the quadrangle. The preceding list of these rocks is possibly in chronological order (oldest to youngest) though most evidence for this is equivocal. As far as can be determined, all of these rocks have injection contacts with Grenville rocks and are pre-Potsdam. With the exception of the Fish Creek alaskite gneiss, these rocks represent only portions of masses that are mainly in adjacent quadrangles or are covered by unconsolidated material or by Paleozoic sedimentary rocks.

The Fish Creek mass, the investigation of which was the main concern of this areal study, is a steeply plunging, nearly isoclinally folded body with an outcrop area of approximately 12 square miles. The outcrop surface is a cross section nearly perpendicular to the axis of the fold. The main part of the mass is a fine-grained, pink alaskite gneiss. Medium-grained, gray-green trondhjemite, which is regarded as a portion of the alaskite magma contaminated by impure marble, forms a discontinuous border facies. All intrusive contacts observed are with highly metamorphosed Precambrian Grenville series marble. The mass is considered to be a phacolith because: (1) it is generally concordant; (2) it occupies the trough of a syncline; (3) it has a general lenticular cross section, and (4) it appears to have resulted from the consolidation of magma that was intruded syntectonically. Phacolithic emplacement is inferred because of marked thickening on the plunging nose of the mass and the presence of sheetlike inclusions within the alaskite. The lack within the mass of a systematic spatial arrangement of alaskite that is apparently undeformed, of alaskite that has a marked cataclastic fabric, and of alaskite that has been recrystallized completely is thought to be corroborative because this arrangement appears to be explained more readily as a result of deformation during the consolidation of the magma than by subsequent deformation of the solid rock.

Upper Cambrian (?) Potsdam sandstone and Theresa formation and Lower Ordovician Ogdensburg dolomite, that occur within the mapped area, have been mapped on a strictly lithologic basis. Much of the area west of Black Lake and a small area near the east border of the quadrangle are underlain by these sedimentary rocks. The Potsdam lies unconformably on the Precambrian crystalline rocks; it grades upwards into the Theresa formation; the Ogdensburg dolomite is separated from the underlying Theresa by a disconformity. Quartzitic conglomerates and breccias are present as lenses in the Potsdam sandstone; some of them are definitely channel fillings rather than a type of basal conglomerate as previously reported. Concretions occur locally in the Potsdam. Because the concretions are transected by sedimentary lamellae continuous with those in the adjacent sandstone, and because the concretions were faulted by preinduration slumping, they are considered to have been formed penecontemporaneous to deposition.

Various building and road materials—sand and gravel, sandstone, dolomite and granite—are available in large quantities in the area. Graphite, magnetite and glass silica sources have been investigated; they cannot be considered to be of commercial interest under present economic conditions.

INTRODUCTION

Location, access and extent of area. The Brier Hill quadrangle is in northwestern New York, on the St. Lawrence River. Most parts of the quadrangle are relatively easily accessible from State Highway 37 and the network of country roads. During the present study, the United States portion of this quadrangle and an additional square mile to the east, in the Ogdensburg quadrangle—totaling about 90 square miles—were mapped geologically on the scale of 1:31,680.

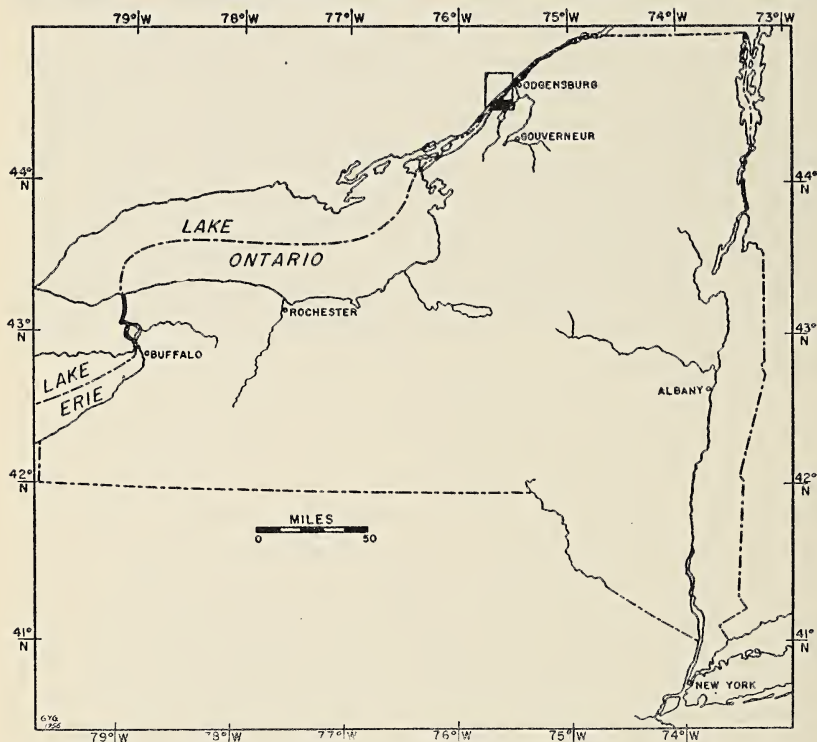


Figure 1. Index map showing location of area.

Earlier investigations. This area was mapped as part of a regional investigation by H. P. Cushing (1916, p. 7), whose "chief purpose in mind in undertaking the areal mapping . . . was to make a careful study of the Beekmantown formation in the district of the Upper St. Lawrence, in order to see how fully it was represented and how it compared with the formation in the Champlain valley."

A. F. Buddington (1929) included the Fish Creek mass, which is in the eastern portion of the Brier Hill area, in his study of the 14 anticlinal phacoliths that he found to occur in the northwest Adirondacks.

Acknowledgments. Five months were spent in the field during 1949 and 1950. This fieldwork was partially supported by a grant from the New York State Science Service. Laboratory work was done at Yale University during the 1949-50 and 1950-51 academic years.¹ James Dwight Dana and Edwin Binney, Jr. Yale University Fellowship grants helped defray laboratory expenses.

The writer thanks the many visitors he had in the field for their interest in his problems. In particular, he wishes to express his appreciation for the suggestions given by R. O. Bloomer, J. G. Broughton, A. F. Buddington, G. V. Carroll, A. E. J. Engel, E. B. Knopf, J. J. Prucha, B. M. Shaub and C. E. Tilley.

The writer is especially indebted to Professor Adolph Knopf for many suggestions, valuable criticism and stimulating discussions on the many and diverse problems encountered in the field and in the laboratory throughout the preparation of the report. Mrs. E. B. Knopf, H. W. Coulter, R. F. Flint, E. R. W. Neale, John Rodgers and Horace Winchell gave suggestions concerning particular problems; J. G. Broughton, A. F. Buddington, W. D. Lowry, and J. J. Prucha read and criticized the original manuscript. These suggestions and criticisms are gratefully acknowledged.

GEOMORPHIC SKETCH

Topography. The area lies within two different topographic provinces—the St. Lawrence lowland and the Piedmont of the Adirondack Mountains. Black Lake forms the natural boundary between these two provinces.

Much of the surface is exposed or only thinly soil-covered bedrock. Therefore, topography is intimately controlled by kind and structure of underlying rocks.

The St. Lawrence lowland, for the most part underlain by flat-lying early Paleozoic sedimentary rocks, consists of a succession of flat surfaces bounded by scarps, rather than one flat surface. Scarps up to 60 feet in height occur along the St. Lawrence River southwest of Morristown, along Chippewa Creek Valley southwest of Demot Road and along the northwest shore of Black Lake. Some of the scarps are lithologically controlled, having resistant sandstone top and bottom flats and less resistant calcareous rock rises; other scarps show no apparent lithological control.

The monotony of this topography is interrupted by the Chippewa Creek Valley, a few ridges and knolls of crystalline rocks, and diverse

¹ This paper is part of a dissertation presented in 1951 for the degree of doctor of philosophy from Yale University.

glacial deposits. Chippewa Creek Valley has a hummocky surface southwest of Brier Hill; it is floored by variable thicknesses of glacial material deposited on an uneven Precambrian rock floor. Ridges, most of which are elongate parallel to the trend of the foliation of the underlying rocks, and knolls are present where Precambrian metamorphic and igneous rocks project above the Paleozoic cover, e.g., the Oak Point and Point Comfort quartzite inliers and the mass of granite that crops out just west of Brier Hill. Locally, glacial deposits diversify the flat landscape.

The Piedmont of the Adirondack Mountains has a highly irregular topography of low relief, much of the area consisting of steep slopes. Crystalline limestone, quartzite, mylonite, migmatites and igneous foliates predominate in the bedrock. The main features are limestone-floored valleys, quartzite and mylonite hills and ridges, and many narrow linear ridges which faithfully follow the trend of the foliation of the gneisses.

Though some of the rounded-off hills may owe their present shape to glacial action, in general, Pleistocene glaciation appears to have modified preglacial topography but slightly. Quarrying and glacial deposits are the only notable modifications that may be attributed to glaciation with any certainty.

Drainage. The main streams flow into the St. Lawrence River, which flows in a general northeasterly direction into the Atlantic Ocean.

The major valleys—the St. Lawrence River, Chippewa Creek, Black Lake and Fish Creek valleys (the last two may actually be one compound valley) show marked parallelism within the area. This parallelism is coincident with one of the joint sets within the area and also is parallel to end-moraine patterns southeast of the mapped area (Taylor, 1924). The St. Lawrence River and Black Lake flow northeastward; Chippewa Creek and Fish Creek flow southwestward. The St. Lawrence River flows through the area in a deep channel (up to 350 feet), whereas most parts of Chippewa Creek, Black Lake and Fish Creek are less than 10 feet deep. However, subsurface data indicate that the bedrock channels of the Chippewa Creek and Black Lake valleys are comparable in depth to the present St. Lawrence River. Though subsurface data are too few to permit determination of the direction of gradient of these channels, barbed tributaries on the southwestward flowing streams, the presence of more and larger bedrock outcrops within the channels in their southwest parts than in their northeast parts, and the fact that the Black Lake channel has a theater head at its southwest end indicate that these bedrock channels deepen to the northeast. At least part of each valley is bounded by

PLATE 3

Examples of contrasting topography



A. St. Lawrence Lowland. Area underlain by flatlying sedimentary rocks; looking south from road intersection east of Oak Point.



B. Irregular topography east of Black Lake. Both views were taken near the center of the Fish Creek Phacolith.

cliffs. The valleys thus delimited by cliffs are comparable in width to the present St. Lawrence River (figure 2). The Chippewa Creek Valley and St. Lawrence River channel become less well-defined to the northeast, having only drift-covered banks. Bedrock terraces occur sporadically along the valleys. The terraces along the southeast side of the St. Lawrence River have no apparent lithological control.

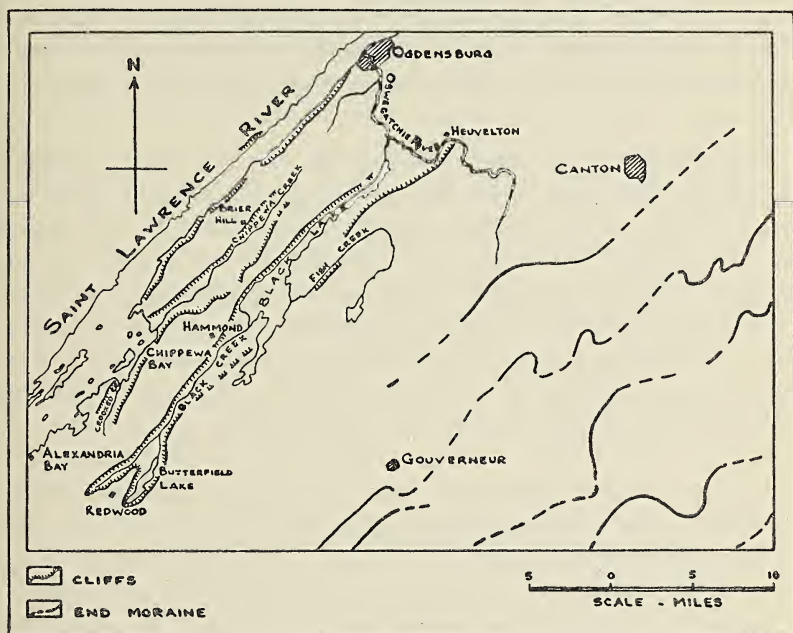


Figure 2. Map showing parallelism of end moraine pattern and cliffed valleys of St. Lawrence River, Chippewa Creek and Black Lake-Black Creek. (End moraine pattern from Taylor, 1924)

The well-defined, cliffed valley of Chippewa Creek may be traced southwestward from Demot Road on the Brier Hill quadrangle, through the Hammond quadrangle, on to the Alexandria Bay quadrangle, where it merges with the St. Lawrence River at Chippewa Bay. A possible continuation of the same channel occurs farther to the southwest across Chippewa Bay along Crooked Creek.

Black Lake Valley is well defined by cliffs where its valley wall is sedimentary rock; its definition is obscure where its wall is metamorphic or igneous rock. The cliffed valley, nearly continuous across the Brier Hill quadrangle, extends to the northeast on the Ogdensburg quadrangle along Black Lake and the portion of the Oswegatchie River that runs southwestward from Heuvelton, and it may be traced to the southwest along Black Lake and Black Creek through this quadrangle, the Hammond quadrangle and on to the Alexandria Bay

quadrangle, where the valley divides just north of Redwood. Black Creek and Butterfield Lake are in the southeastern branch of the valley; a tributary creek to Black Creek is in the other branch. Both valleys have theater heads in bedrock.

The origin of this drainage has not been established. More extensive field mapping of the channels combined with pollen analyses and possibly with radiocarbon dating of material from the swamps in the Chippewa Creek and Black Lake valleys and the establishment of Pleistocene chronology in the region may clarify the history of the drainage.

The following hypothesis, based on the meager data now available, is offered. The main valleys are parallel to the joint set, N. 25° E. to N. 45° E., which strikes nearly perpendicular to the trend of the general slope of the land. Therefore, the present general drainage pattern probably has existed as long as these conditions have obtained. The fact that the Black Lake and Chippewa Creek bedrock valleys and the St. Lawrence channel are comparable in size is regarded as a consequence of their having carried like volumes of water at some time. When one considers the size of these channels—the average depth is greater than 150 feet and the average width is approximately 1¼ miles—and the fact that all lie within a 9-mile span, it appears doubtful that they were ever coexistent carriers of major streams. The parallelism between these valleys and the main end moraine pattern occurring to the southeast suggests that the valleys were formed or at least enlarged by large streams marginal to the ice front. This suggestion is corroborated by the distribution of bedrock terraces having no apparent lithological control—such terraces have been found to occur only on the valley walls that face the former edge of an ice sheet. The present major stream, the St. Lawrence River, is in the most northwesterly valley of this general magnitude, lying in the lowland between the more rugged Adirondack Mountains and the Canadian Shield and offering a direct connection between Lake Ontario and the Atlantic Ocean. Therefore, the position of the valley with reference to the retreating ice sheet was probably the control responsible for its selection. The other valleys were filled with till and outwash material upon which the lesser drainage arteries now flow. All valleys may be attributed to a single glacial retreat or advance, readvances and retreats of one ice sheet, or to movements of different ice sheets under the present hypothesis. Definite relative dating of the periods of formation and period or periods when these valleys were utilized by major streams may be possible with extended investigation. However, it may be very difficult because all channels may have gone through many stages—

many characteristics commonly utilized in such relative dating are found in all these valleys (e.g., striated outcrops occur in all the valleys and portions of the tops of cliffs bordering all valleys are rounded off and have been glacially striated).

Minor elements of the drainage have more obvious origins. Chippewa Creek flows southwestward because it is flowing on a fill that has a southwestward gradient. Black Lake is a lake within the area rather than a stream, as in the same valley to the north and to the south, because it was dammed by outwash material partly protected by rock islands at the Edwardsville "narrows."

Glacial deposits. No systematic mapping of the unconsolidated deposits was carried on in conjunction with this study of the bedrock geology. Ten soil series and 17 soil types have been recognized and mapped in this area (Lounsbury, et al., 1925). The kind of glacial deposit from which each type was probably derived was also determined by the authors. Though modifications of this mapping are possible, it is considered impracticable until the glacial stratigraphy has been determined for the region. Because there are no sizeable cuts in the unconsolidated material in this area, this will be very difficult without intensive boring.

Clayey till with many granitic, quartzitic and sandstone boulders and pebbles is dominant in the northern part of the quadrangle. This ground moraine appears to thicken toward the north, though this may be but a local change. Outwash deposits (or possibly delta deposits) with excellent cut and fill channels, crossbedding, many abrupt changes of grain size and a few large, ice-rafted (?) boulders are present along the Chippewa Creek Valley south of Brier Hill and along the Black Lake Valley at Edwardsville. Gray lacustrine (Lake Iroquois ?) clays are present under the soil cover in many places within the area—especially in the southern part. At Edwardsville, well data suggest the presence of lacustrine clays beneath the outwash deposit. Stratified kame material, some of which suggests esker deposits, occurs along Bromaghin Road, Monkey Hill Road and Haggart Road south of Ogdensburg. Peat is found along Black Lake, Fish Creek, Chippewa Creek and some of their tributaries. All unconsolidated deposits, except the peat and the recent material on the bottoms of the different waterways, are well oxidized. Most unweathered subsoil is below at least 2 feet of soil, though the soil zone ranges from 6 inches to 45 inches in thickness.

Glacial movement. Most sandstone and many granite outcrops have either striated surfaces, friction cracks or both. Many ridges of Precambrian rocks have stoss and lee slopes, with the lee slopes facing

south. All observed crescentic gouges are convex toward the south and all chatter marks are concave toward the south. Glacial erratics of peculiar types (e.g., anorthosite) have known possible sources to the north and no known possible source to the south (see Martens, 1925). There are, however, possible sources for some of these rocks to the east in the Adirondack Mountains, and such a derivation area cannot be completely outlawed on the basis of present data. The strike and direction of last effective movement of ice, based on these data, trends about S. 15° W. Few measurements deviated more than 10° from this figure. One notable exception occurs about one-half mile north of the southern border of the area, on the east side of Route 37, where there is a small flat area in which striae trend S. 27° E. and S. 12° W. The S. 27° E. striae are superposed on the S. 12° W. striae. No explanation for this local anomaly was found.

The trend of the ice movement in the St. Lawrence Valley was formerly believed to deviate from the regional trend, becoming more nearly parallel to the strike of the valley. This belief is not supported by observations of outcrop surfaces on Bogardus Island in the St. Lawrence River and those on the granite at the granite-Potsdam sandstone contact near the northeast end of Oak Point, where the striae make a marked angle with the trend of the river's valley.

Recent weathering and erosion. All rocks within the area have potential or actual joints that serve as loci for concentrating the effects of weathering processes. Modified joints and transported joint blocks evidence this control.

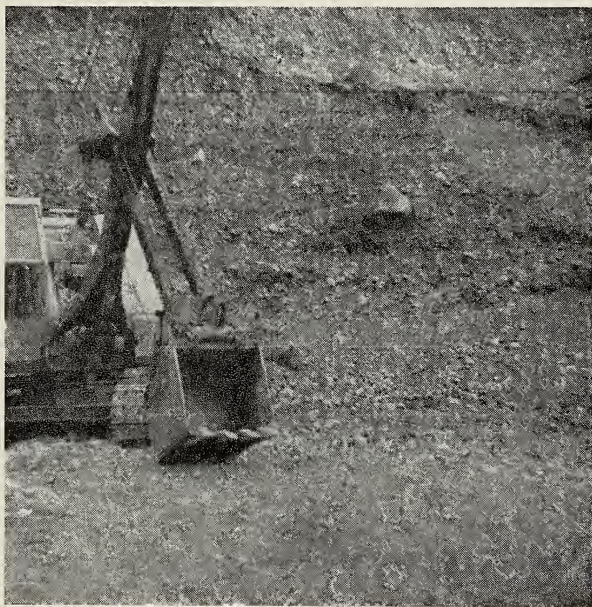
The chief manifestations of mechanical weathering are frost and plant wedging. Blocks apparently sprung apart by frost wedging are common. A good example of the type of plant wedging that is rather common in this area is shown in plate 6.

Chemical weathering is especially important in the crystalline limestone, pyrite-bearing schists, quartz-oligoclase phanerites, melanocratic foliates and calcareous Paleozoic rocks. Most crystalline limestone outcrops are covered with loose, granular, rusty-colored calcareous sand; pyrite-bearing schists, compact where fresh, are rusty-colored and friable on weathered surfaces; quartz-oligoclase phanerites show white clayey material in a quartz mesh up to depths of one inch; amphibolites, pyroxene-plagioclase foliates and their variants, that occur as xenoliths in alaskite gneiss, weather more rapidly than their granitic host, leaving the alaskite in relief. All calcareous and dolomitic Paleozoic rocks show the results of chemical weathering, such as chamois-like appearing surfaces on some of the dolomites, the smooth surfaces and rounded corners and edges on joint surfaces and bedding plane intersections,

PLATE 4
Outwash material



A. Note cross-bedding, cut and fill features, range of grain size and abrupt changes of grain size. (Stout Pit south of Brier Hill)



B. Note especially the large boulder to the right of center. This may be an ice-rafted boulder. (Edwardsville Pit)

PLATE 5

Friction cracks and an erratic



A. Friction cracks in alaskite; glacial movement indicated by these "crescentic gouges" is away from observer (near end of east leg of the Fish Creek mass).



B. Erratic is a 7 feet x 11 feet x 7 feet boulder of Precambrian biotite granite gneiss resting on Cambrian Potsdam sandstone. (Oak Point)

PLATE 6
Tree wedging



The main tree is a hard maple approximately 140 years old; the joint block that has been moved—apparently by tree wedging, possibly aided by frost action—weighs more than 5 tons (on west leg of Fish Creek Phacolith).

the presence of travertine on joint surfaces in rocks below calcareous rocks, and the weathering-out of sand grains and cobbles where calcareous cement was present in sandstones, conglomerates and breccias.

Hydraulic action and abrasion—especially effective in the spring when the ice is “going out”—have produced many undercut cliffs along the St. Lawrence River. Huge slabs (some having dimensions as large as 30 feet x 30 feet x 8 feet), which have fallen because of the undercutting, occur along the river's shore. Such undercutting apparently is prompted by either chemical weathering or by hardness differences; it is more marked in the Potsdam formation, where calcareous cement is present in notable amounts, than in the Potsdam where the cement is predominantly silica.

THE ROCKS

General statement. The oldest known rocks in the area are metamorphosed sedimentary rocks belonging to the Precambrian Grenville series. Crystalline limestone, quartzite and various gneissic rocks, many of which show contact modifications, predominate. These rocks

TABLE 1

Generalized section of rocks present in this area*

AGE	FORMATION	CHARACTER	THICKNESS
Ordovician	Ogdensburg dolomite (Beekmantown?)	Alternating beds of massive blue-gray, granular dolomite, and thin-bedded, buff-gray fine-grained dolomite; sporadic beds of gray calcareous sandstone occur near the base.	120 ft.
	disconformity		
Cambrian (?)	Theresa formation	Alternating beds of white sandstone, gray calcareous sandstone, and blue-gray sandy limestones.	140 ft.
	Potsdam sandstone	White, red, buff and color-laminated, vitreous sandstone; local breccia and conglomerate lenses comprised predominantly of quartzite particles.	up to at least 125 ft.
	UNCONFORMITY		
Precambrian	Igneous rocks	“Basic” dikes Aplite and pegmatite Amphibolitized melanocratic dikes Alaskitic gneiss (has trondhjemite border facies locally). Granitic augen gneiss Quartz syenite gneiss Biotite granite	
	Grenville series	This series contains crystalline limestone (marble), quartzite and diverse foliates and their contact modifications.	

* Based in part on the work of H. P. Cushing (1916, p. 24) and A. F. Buddington (1939, p. 198).

are highly distorted and have a very patchy distribution, and consequently, their sequence and thicknesses are unknown at present. Granitic, syenitic and basaltic magmas have invaded the Grenville Series rocks. Following the igneous action, which was apparently limited to Precambrian time, there was marked erosion as is evidenced by an erosion surface on the Precambrian rocks beneath.

The Paleozoic rocks, sandstones, sedimentary breccias, conglomerates, calcareous sandstones, sandy limestones and dolomites, are limited to the Cambrian (?)¹ and Ordovician systems. They show no marked unconformities within their sequence, though in some places there is evidence of erosion between the Cambrian (?) and Ordovician rocks. No Mesozoic or Cenozoic rocks were recognized to occur within the area.

GRENVILLE METAMORPHIC ROCKS

General statement. According to the New York State and United States Geological Surveys' usage, Grenville series denotes a Precambrian provincial series of metamorphosed sedimentary rocks in the Adirondack Region of northern New York and in Ontario and Quebec, Canada. The series is considered to be Precambrian because it was intruded locally by magmas which solidified and were uncovered by weathering and erosion before the deposition of late Cambrian (?) (Potsdam) sediments.

This view is supported by radioactive age determination of minerals which occur in pegmatites that cut rocks thought to belong to the Grenville series. Nine localities within the Grenville province have yielded uraninite or other radioactive minerals that have been dated. Seven of these dates are very similar and average about —1070 million years; the other two are much younger. Shaub (1940, p. 481) presented a map showing the locations from which the dated materials came. Uraninite from the McLearn pegmatite located near Richville Station, dated as —1030^a million years (Class IV), is between 10 and 15 miles from Grenville outcrops within this area. The pegmatite is in and parallel to the strike of highly metamorphosed limestone of the Grenville series not unlike that occurring in this area.

Highly metamorphosed quartzite, diverse gneisses, coarsely crystalline marble and contact modifications of each present in the Brier

¹ D. W. Fisher (personal communication) questions the Cambrian age for the Potsdam and Theresa formations. Because of possible future changes as an outcome of Fisher's investigations, *Cambrian* (?) is used when these formations are alluded to in this paper.

^a The figure —1030 million years is obtained by using Wickman's (1943) chart and the microchemical analysis figures for uranium, thorium and lead quoted by Shaub (1940).

Hill area are considered to belong to the series in accordance with the above stated usage. The formations are folded intricately and are complicated further structurally by the presence of many igneous bodies.

The top and bottom, the thickness and the sequence of formations (or members) within this highly complex series have not been established. The floor upon which the Grenville sediments were deposited has not been recognized. However, the hypotheses must be entertained that the floor is represented by some of the gneisses whose relations to these metasedimentites cannot be established definitely, e.g., the biotite granite gneiss of the Oak Point and American Island outcrop areas, and/or by the alaskite that appears to intrude the Grenville rocks, i.e., the intrusive relationships exist only because of partial or complete remelting and local injection of the materials of the floor upon which the Grenville rocks were deposited. Minor faults which may be due to postdepositional slump occur locally in the quartzites. Although study of these has so far proved fruitless, these features may prove to be useful geopetal¹ features in the future. Until the base of the series and a recognizable sequence of units can be established, estimates of thickness of the Grenville and naming of structural features such as folds on any basis except one of spatial orientation will be most hazardous.

Structurally, the Grenville rocks are very complex. Although regional trends are apparent, and most dips of planar features and plunges of linear features exceed 60°, locally they range from 0° to 90° within a few yards. That much of the marble has undergone marked plastic working further complicates the structure of these rocks.

Mapping on the 1:31,680 maps and sampling of this group of rocks posed two major problems: (1) it is impossible to show most of the smaller lithic units and minor structures on the map; (2) because lithological units differ within short distances and contain many tectonic breccia fragments, it is practically impossible to collect all rock types present. Only predominant rock types are indicated on the map. For example, the area represented by the marble symbol on the map may be underlain by pure or impure marble, diverse petrographic types that occur as fragments in a tectonic breccia phase of the marble or as lenses within the marble, or contact modifications of any of these phases. Structure symbols shown on the map are representations of averages of many readings. The symbol  is used in many of the

¹ Bruno Sander proposed this convenient adjective to refer to any character that enables one to determine what was the relation of "top" and "bottom" at the time when the rock was formed.

limestone areas in lieu of commonly used symbols because, in the opinion of the writer, this symbol better suggests the structural complexities present. Sampling connected with this investigation was limited to the common rock types, the noticeably different rock types found as lenses and as fragments in the tectonic breccia, and a few collections made along traverses across contact zones between intrusions and rocks of the Grenville series.

Quartzite. Grenville quartzite occurs in many places within the area. Seven outcrop areas are of sufficient size to be shown on the map: Five isolated areas are in or near the St. Lawrence River—Bogardus Island is nearly all quartzite, the western tip of American Island is quartzite, two inliers of quartzite occur in the Paleozoic sedimentary rocks near Point Comfort, and one inlier is present approximately one-half mile east of Oak Point. The other two areas are east of Black Lake, where quartzite is intimately associated with the Popes Mills quartz syenite mass.

The quartzite that crops out near the St. Lawrence River is characteristically a massive, white, vitreous, medium-grained quartzite with many small irregularly shaped cavities, most of which are partly filled with pyrite or lined with secondary iron material. Gray and white laminated quartzite and a sheared quartzite with iron-stained films along the irregular shear surfaces occur locally. The iron stain is possibly derived from the weathering of pyrite which is present in most of the fresh quartzite.

Quartz veins and granitic pegmatite dikelets are present in all of the outcrop areas. Many masses of metamorphic rocks having ambiguous or obscured field relationships occur with the quartzite beds. They are of questionable origin. Some of the masses appear to be portions of igneous bodies; others may be interbedded Grenville sediments. A few of the petrographic types that occur in these masses are pyritiferous biotite-pyroxene gneiss, phlogopite gneiss, biotite schist, hornblende-biotite gneiss and diverse granitic gneisses. Stringers composed of extremely fine, equidimensional tourmaline (schorlite) grains, pyroxene veinlets, pink granitic pegmatite, specular hematite along joints in the quartzite adjacent to one of the pegmatites, and biotite granite masses also occur in the Point Comfort inlier. Tortuous dikelets of gray-white aplite cut the lamination of the Bogardus Island quartzite. Basic dikes and detrital sandstone dikes are present in the Oak Point inlier.

The quartzite as seen in thin section consists predominantly of quartz, with minor amounts of albite, microcline, microperthite and traces of tourmaline, magnetite, pyrite, apatite, zircon, sphene, allanite

and rutile. The typical quartzite is seen to be a mosaic of recrystallized quartz grains some of which have regular boundaries and others of which have sutured boundaries. Most of the quartz grains range from .5 to 1.0 mm. in diameter and all grains show undulatory extinction between crossed nicols. No detrital grains of quartz or relicts of such grains have been recognized in the thin sections. The feldspars that have been determined definitely are albite, microcline and microperthite. These feldspars are of three general modes of occurrence: (1) small rounded grains included in quartz grains; (2) grains that are about the same size as the quartz grains and fit into the general mosaic pattern, and (3) large clusters of grains that have many quartz inclusions.

The feldspars were probably derived in part from magmatic emanations and in part by reconstitution of originally impure quartzite during recrystallization. The other minerals generally comprise less than 5 percent of the quartzite. A few sections contain large grains of tourmaline (schorlite). Chloritic material, some of which is evidently an alteration product after biotite, is found in most sections. Magnetite, pyrite, apatite, zircon and sphene occur in most sections. Allanite and rutile have been recognized in one section each. With the exception of a few rounded grains of zircon, magnetite and sphene, none of the minerals occurs as grains that suggest a detrital origin.

Topographically, the quartzite occurs as ridges which are elongate parallel to the general trend of the prominent s-planes in the quartzite. The present elevations and occurrences of these quartzite inliers indicate that the ridges were prominent features of the pre-Potsdam landscape. The steep sides of these ridges, as evidenced where Paleozoic rocks have been eroded away from the contacts, and the fact that the fragments of the Potsdam conglomerates and sedimentary breccias are nearly all of similar quartzite suggest that these quartzites were one of the most resistant rocks of the Grenville sequence under the conditions of pre-Potsdam weathering.

One phenomenon was observed in the laminated quartzite that may prove to be of great value in unraveling the sequence and structure of the rocks of the Grenville series if it is present in enough critical areas. Minor faults occur that appear to be similar to faults of penecontemporaneous to deposition slump type. If the lamination is relict sedimentary lamination, these faults may be of use as geopetal features.

Locally, joint sets are present in the quartzites. Most of the joints are nearly vertical. Some of them are closely spaced, less than 2 cm. apart; others are spaced as far as 2 m. apart. None of the sets has any apparent regional extent. A few examples of such sets are:

N. 10° E. and N. 75° E. near the northeast end of the Oak Point inlier; N. 45° E. and N. 85° E. near the southwest end of the Point Comfort inlier, and N. 50° W. in the central part of the Point Comfort inlier. At least some of the joints were obviously formed before Potsdam sedimentation, because they are filled by detrital Potsdam sandstone.

Although these five widely separated outcrop areas cannot be correlated, they possibly may be related. In the Brockville-Mallorytown area across the St. Lawrence River from this area, Wright (1923, p. 20) suggested that similar quartzite beds may have attained their present structural attitude—they all strike northeast and dip steeply to the northwest—by being pushed aside by the intrusion of granitic magma. This hypothesis was suggested because the quartzites dip away from the area to the southeast which is underlain predominantly by granite. The quartzite outcrops along the St. Lawrence River in the Brier Hill area are on the southeastern side of this same granite complex. They strike generally northeast, parallel to the granite belt, and have in general a steep dip toward the southeast. This evidence could be construed to corroborate Wright's hypothesis, or to suggest the presence of a major anticline with its axial plane nearly coincident with the St. Lawrence River.

Two fairly large outcrops and many smaller outcrops of quartzite are intimately associated with the Popes Mills quartz syenite mass. The quartzite occurs in beds that are in general concordant with the structure of the syenite body. Typically, this is a black and white laminated, subvitreous, fine-grained quartzite. Locally, it tends to part along planes parallel to the lamination. Generally, it has a marked banding which reflects alternate concentrations of dark and light laminae. Most of the quartzite contains a notable amount of white and pink feldspar. This feldspar content, which is greater immediately adjacent to the contacts with the syenite and is wider where the syenite cuts across the lamination in the quartzite, probably represents feldspathization by solutions from the syenite.

In thin sections, the feldspathized quartzite is seen to be a mosaic of sutured quartz with a few large porphyroblasts of feldspars. Stringers of magnetite and a chloritized mineral outline the lamellae. Both euhedral and rounded zircons occur in most sections; the latter may be detrital grains. Biotite, hornblende, diopside and chlorite are present as augen in a few sections. Apatite and muscovite are present as minor amounts in some sections.

Quartz comprises more than 90 percent of the quartzite in all but the most feldspathized sections. Although evidence of cataclasis is

absent, all of the quartz has undulatory extinction, which indicates that it has been strained. Where individual units of the magnetite stringers are longer than adjacent quartz grains, the individual quartz grains do not cross the stringers. However, where the magnetite units are small, the recrystallized quartz grains generally contain the magnetite as inclusions. One section shows a definite preferred optical orientation of the quartz. This preferred orientation may indicate recrystallization under the influence of directed forces.

Porphyroblasts of both albite and microcline are present in the quartzite. The porphyroblasts range to 2 mm. in diameter. Both feldspars are partly altered—the albite is sericitized; the microcline is kaolinized. The feldspar content as already mentioned increases toward the contact of the quartzite with quartz syenite.

Marble.¹ Marble crops out in two areas near the southern margin of the Brier Hill quadrangle, east of Black Lake. Typically, the marble outcrops are either surfaces covered with a rust-colored calcite sand or are glaciated surfaces that subsequently have been weathered, as is manifest by differential solution phenomena. The marble of the two areas is similar in character, though it appears to have greater structural complexity and a wider range in mineral composition in the area nearer Black Lake.

The marble is wholly crystalline at all observed outcrops. However, it differs in character greatly from place to place. Though relatively pure marble comprises the greatest proportion of the unit within this area, much of the marble contains notable percentages of one or more minerals such as apatite, chondrodite, diopside, feldspar, graphite, phlogopite, pyrite, quartz, scapolite, serpentine, sphene and spinel. Locally, the minerals are disseminated through the marble, but commonly they are more abundant in certain irregular layers. This feature, coupled with the fact that the purer phases are generally coarser grained (5 mm.) than those that are less pure, gives the marble a stratified appearance in the field. The presence of many Mg-bearing minerals in the impure layers suggests that this stratified appearance may be a manifestation of original compositional differences in the sediments, i.e., interlayered calcitic and dolomitic strata.

The petrography of the layers and possible interpretations of their origin are discussed in the part of the paper concerned with the con-

¹ The word marble is used instead of the synonymous term "crystalline limestone" because the writer prefers to use monomial rock names where possible. Marble has two definitions: commercially, it refers to any calcareous rock capable of taking a polish; petrographically, it is the name given to a completely recrystallized limestone in which all traces of clastic and organic structure have been effaced. In this report, it is used in the petrographic sense.

tact metamorphism caused by the Fish Creek alaskite. The general character of the unit is further complicated by the presence of pegmatitic nodules and masses, aplite dikes and sills, basic dikes and sills, tectonic breccia fragments, lenses of unknown origin and by the effects of dynamic metamorphism.

In thin section calcite is seen to comprise more than 95 percent of the "pure" marbles. Most sections contain minor amounts of quartz, graphite, apatite and sphene (commonly partly altered to anatase or to an opaque mineral—ilmenite?—which is, in turn, partly altered to leucoxene). Spinel and chondrodite (either fresh or serpentinized) or scapolite and a pyroxene of the diopside-hedenbergite series are present in many sections. Plagioclase, micropertthite, myrmekite, phlogopite, fluorite and clinozoisite are sporadic accessory minerals. Typically the marble has a mosaic texture, but some sections show a replacement texture with sutured intergranular borders. Discrete grains of recrystallized quartz, plagioclase feldspar, myrmekite and crystalloblastic aggregates of these minerals are present in this latter type. The replacement features and penetration of the calcite into all minor potential cavities suggest that this rock may be a metamorphosed clastic member of the marble unit. Another interesting feature is present in a section containing serpentinized chondrodite: a carbonate (Mg-rich ?) occurs along cleavage planes of the main calcite grains, out of optical continuity with these grains. If this is a carbonate high in magnesium content, it may have been formed as a byproduct of the serpentinization of the chondrodite.

The impure marbles are believed to be former dolomitic strata that have been dedolomitized and reconstituted during contact metamorphism. This probably took place when metasomatically active fluids containing boron, fluorine, chlorine and probably phosphorus, as indicated respectively by the minerals tourmaline, chondrodite, scapolite and apatite, were available.

Most of the impure marble may be placed in one of four major categories: (1) quartzose marble; (2) spinel-bearing chondrodite marble; (3) serpentine marble (ophicalcite)—serpentine has been derived from chondrodite; and (4) sphenic pyroxene (hedenbergite-diopside series)—scapolite marble. Some of the impure phases grade into rocks composed wholly of these minerals.

Although the grains show no noticeable shape orientation, either megascopically or microscopically (there are local exceptions to this), there is evidence that recrystallization occurred during deformation. The cleavage and twinning planes of the calcite in both the pure and impure marbles generally show marked bending.

PLATE 7
Tectonic breccia



A. Well-banded phase of Grenville marble with tectonic breccia fragments of silicate rock included (south of Fish Creek mass)



B. Typical tectonic breccia (south of Fish Creek mass)

PLATE 8
Tectonic breccia



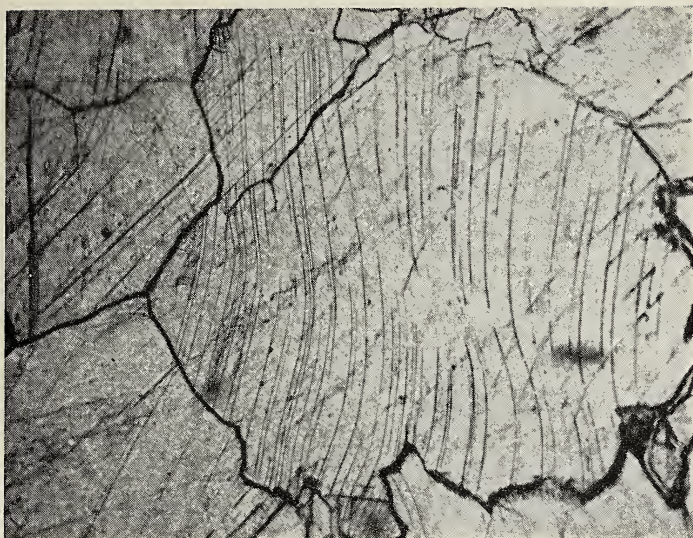
A. Folded fragments of silicate rock within the Grenville marble (south of Fish Creek mass)



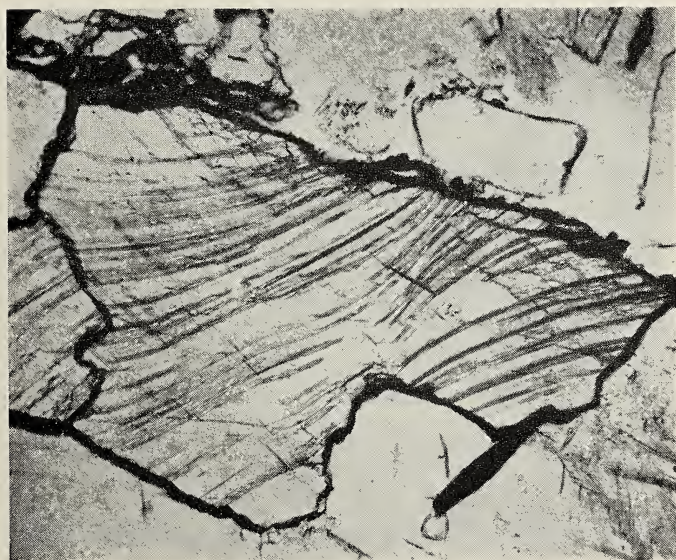
B. Silicate rock fragment in marble—note distortion of the silicate fragment suggesting that it was plastic—or in some similar state—during flowage of the marble (near Grenville marble—quartz syenite gneiss contact)

PLATE 9

Distorted calcite in Grenville marble



A. Bent cleavage planes (x 60)



B. Bent twinning planes (x 60)

Structural features of the marble. Only a few scattered outcrops of marble are present in the area near the southeast corner of the Brier Hill quadrangle. Therefore, the structure is not well defined. However, the general strike of the marble, though strongly divergent locally, is N. 40° E. and all dips are steep, ranging from 80° W. to 75° E.

The structure in the area nearer Black Lake is apparently much more complex. No major folds were recognized in the field. However, if the structure is interpreted according to the dictum of T. N. Dale (1894, p. 158), that in an area of structural unity small folds faithfully imitate the major folds, it appears that the marble in this area forms a syncline in which the axial plane dips steeply to the east and the axis plunges steeply to the northeast. Engel (1949, p. 774) has further suggested that in this province (Grenville of the northwest Adirondacks) the most symmetrical minor folds commonly occur in the apex areas of the major folds. Nearly symmetrical minor folds are present on the point on the east shore of Black Lake just north of the southern border of the quadrangle. These symmetrical folds coincide with the southwestward extension of the axial plane of the folded Fish Creek alaskite body. This coupled with the fact that their axial planes are nearly parallel to the axial plane of the Fish Creek mass suggests general structural concordance of the marble and the Fish Creek body. This interpretation is based on orientations of minor folds as outlined by impure layers and discontinuous zones of inclusions in the marble. However, the significance of the observations is equivocal because:

1. The origin of the layers and of the discontinuous zones of inclusions in the marble have not been established;
2. There has been intense plastic working of the marble;
3. The trends of many of the small folds diverge from the apparent general trend.

1. The marble is so completely recrystallized and reconstituted and has been so markedly deformed that interpretation of most lithic layers as former sedimentary strata is equivocal. However, as stated above, the writer believes that the impure, Mg-rich marble layers may represent former dolomitic strata. The origin of the discontinuous zones of inclusions is even more enigmatic. Many diverse types of highly metamorphosed rocks occur as inclusions. They may have been incorporated into the marble unit:

- a. During the sedimentation cycle as fragments of preexisting rocks,
- b. As intercalated sedimentary layers that have been dismembered and had their dismembered fragments "floated" apart,
- c. As minor intrusions of igneous material which have since been broken up and had their parts "floated" apart, and/or
- d. By the plucking action of "flowing" marble as it moved past adjacent units.

No observed features either support or preclude the possibility that the fragments may have been deposited as such. Within the general region, all stages from continuous intercalated silicate layers through layers of dismembered but nearly

contiguous fragments of similar petrographic types to discontinuous zones of inclusions occur. The fact that some of the fragments have relict igneous textures indicates that they were minor dikes and/or sills in the marble before they were dismembered. The plucking action of the plastically worked marble where it has "flowed" along contacts is very apparent—in some places, certain scars in adjacent rocks and fragments in the marble can be matched with certainty.

Thus it appears that some of the zones were formed by dismembering of former sedimentary layers and igneous masses with subsequent "floating" apart of fragments in the more mobile marble, whereas others may have been formed by the plucking action of "flowing" marble. It is doubted that any of the fragments are original sedimentary fragments. Regardless of their origin(s), these zones, on the basis of their inherent characteristics, are tectonic breccias. Many of the tectonic breccia fragments are contorted. If the fragments were incorporated into the marble as sedimentary layers or as igneous masses, they would have to have been folded within the unit; if they were incorporated by the plucking action of marble "flowing" by the adjacent formations, they could have been folded either before or after introduction into the marble.

Therefore, a second problem is: Were the fragments folded before or after they became enclosed in the marble—that is, do the minor folds reflect the movements that affected the marble host or do they have no genetic connection? When one observes the great differences in competencies of the different components of this unit and also how even small differences in competence—as between pure and impure marbles—have had marked effect on the structures (e.g., impure layers are breached in many places and pure marble has flowed into the breaches) and how the marble appears to have been completely incompetent (unable to transmit any stresses over great distances without mutual displacement of component parts) during deformation, it is difficult to visualize any type of deformation that would account for intense folding of discrete tectonic breccia fragments while within the marble. However, the alternative view that the fragments were folded before being incorporated into the marble appears to be even more untenable when the empirical data are taken into account:

a. Fragments in zones that are contiguous with intercalated layers and thus probably derived from such layers are folded similarly to discrete fragments whose origin(s) is (are) uncertain.

b. There is a marked areal trend of the dips of the axial planes of the folds and the plunges of fold axes which is apparently independent of the shapes of the individual fragments—thus, nearly precluding the possibility that this trend is due to shape orientation of foreign fragments that were incorporated into the marble after they were folded.

c. The structures in the marble, where apparent, approach concordance with the fragments adjacent to their contacts.

The anomaly that the fragments were folded after their enclosure in the marble despite the fact that the marble was so utterly incompetent to transmit stresses may be resolved by setting up any one of a number of conditions under which the differences in competency between the rocks involved would be less. The conclusion regarding this first possible variable which affects the validity of the structural interpretation is that the most of the minor folds as outlined by the layers and tectonic breccia zones do reflect the movements in and thus the pattern of the folds of the marble host.

2 and 3. Plasticity of the marble and divergences of the trends of some of the minor folds from the general areal trend are possibly interrelated. Therefore, these two aspects will be discussed together. Plasticity is marked by such features as:

a. Plastic dikes of marble that have intruded adjacent, more rigid rocks,

b. Plucking of rock fragments from the adjacent rocks by "flowing" marble,

c. Filling of breaches between parts of more competent beds by marble that has "flowed" in from adjacent layers,

d. "Flow" banding around the more nearly equidimensional tectonic breccia fragments, and possibly by

e. Divergences of the trends of some minor folds from the general areal trend.

However, the fact that the marble in this area has undergone plastic working is not the main concern; whether there has been considerable differential movement within the unit is of main importance. If there have been considerable differential movements within the marble, the present orientation of at least some of the tectonic breccia fragments may be due to this "flowing" rather than to the movement(s) which was (were) responsible for the folding of the fragments. If this is true, the structure cannot be interpreted correctly on the basis of the present orientations of all folded fragments.

On the basis of the fact that few folded fragments deviate markedly from the areal trend as defined by a statistical analysis of the minor folds, however, it is concluded that differential flow had but little effect on the present orientation of a large proportion of the fragments. This conclusion would be substantiated further if an explanation could be found for the orientation of the fragments whose trends do deviate from the areal trend, showing why they do so deviate whereas nearby fragments do not.

The outcrops on the small point on the east shore of Black Lake, just north of the southern border of the mapped area have been subjected to such an investigation. The minor folds at the northern end of the point have fold axes that plunge nearly vertically—in coincidence with the areal trend; at the southern end of the point minor folds occur that have nearly horizontal axes. Such divergence within so small distances may be accounted for by assuming that:

a. The fragments could be parts of a single set of folds having folded axes. Such folds would be similar to folds having culminations and depressions. Engel (personal communication) has found folds having similarly bent axes well outlined in one of the mines in the Gouverneur area, just southeast of this area.

b. Some of the fragments were folded before being incorporated into the marble by the plucking action of a "flowing" marble. Discrete fragments would then have any distribution, with the orientations at this locality being one of almost infinite number of possible orientations.

c. Faulting occurred postfolding, giving the fragments such orientations. Other evidences of this faulting would have been subsequently obscured by plastic working of the marble.

d. The folded fragments were folded in their present relative positions. The fact that their axes are at right angles to each other could be accounted for by the presence of an unconformity or by discrete fragments having their long dimensions at right angles before folding.

e. The fragments were "floated" apart after being folded with differential flow accounting for the orientations.

Thus far, no evidence that precludes any of these possible modes of formation has been found. However, one feature that may be of importance and that is certainly suggestive is that most contorted fragments whose orientations deviate from the areal trend are near large tectonic breccia fragments or lenses in the marble. Such areas probably would be most susceptible to differential flow during plastic working of the marble. Therefore, it is believed that at least some of the fragments whose parameters deviate from the areal trend owe their orientations to such differential flow. If this conclusion is valid, it follows that the structure as defined by a statistical analysis of the orientations of minor folds is probably correct—especially where large areas of the marble have many small included fragments but are relatively free from large tectonic breccia fragments and/or lenses of more rigid rocks.

In conclusion, although most of the evidence cited could be construed either to prove or to disprove the validity of the structural interpretation given—that the marble in the area forms a syncline that plunges steeply to the north and whose axial plane dips steeply to the east—the interpretation does appear to fit the empirical facts best.

Other rocks of the Grenville series. Lenses of biotite mortar gneiss, phlogopite gneiss-schist and foliates that occur within the marble unit and garnet gneiss and melanocratic foliates that occur as xenoliths in some of the igneous masses may represent members of the Grenville series. The lenses are so similar to some of the large tectonic breccia fragments that they cannot be distinguished from them. They may represent siliceous or aluminous sediments intercalated in the originally predominantly limestone sequence. The petrography, field relations and origin of the melanocratic foliates are considered in the following section; the garnet gneiss is described and its genesis discussed in the part of this paper concerned with metamorphism associated with the Fish Creek alaskite.

ORIGIN OF THE MELANOCRATIC FOLIATES

General statement of the problem. Dark gray and black gneissic rocks that comprise many different petrographic types, e.g., amphibolite, pyroxene-plagioclase foliates and intermediate types, many of which contain notable amounts of biotite, are designated "melanocratic foliates" in this report. These rocks have been grouped under the single term "amphibolite" in many previous reports (e.g., Cushing, 1925, pp. 33-38 and Buddington, 1929, pp. 94-96). They are not called amphibolites in this report because many of them in this area do not fit the definition of amphibolite (see table 2).

These diverse rock types are grouped because they are intimately related in their occurrences and because most of them cannot be distinguished megascopically. Most of these melanocratic foliates occur as inclusions in granitic masses, the greatest concentration occurring as inclusions in the Fish Creek alaskite mass.

The occurrences, mineral compositions and textures of these rocks, with few exceptions, lend themselves to several genetic interpretations. Therefore, the problem of determining their genesis is extremely difficult.

Some similar dark gneissic rocks that occur within the Fish Creek alaskite body are metamorphosed melanocratic dikes that cut the foliation of the alaskite and cut tabular inclusions in the alaskite; these have apparent origins. However, most of the melanocratic foliates have less distinct field relationships. The discussion below is concerned chiefly with the latter group.

Field relationships of the melanocratic foliates. The field occurrences of these foliates are summarized below in tabular form to facilitate the genetic discussion that follows. Although all the field

facts do not appear to bear on the origin of the melanocratic foliates, all facts must be in harmony with any genesis suggested, so all features noted in the field and in the laboratory are listed.

1. Most of the melanocratic foliates occur as inclusions in the granitic rocks of the area. The greatest bulk of these inclusions occur in the Fish Creek alaskite mass. A few inclusions that have the same general petrography are present in the other granitic masses, e.g., in the Popes Mills syenite mass and the granitic augen gneiss northeast of Popes Mills, in the trondhjemite border facies of the Fish Creek mass, in the marble tectonic breccia and in the garnet gneiss xenoliths in the Fish Creek phacolith. Dikes petrographically similar to the inclusions cut the foliation of the alaskite and cut some of the melanocratic gneissic inclusions within the alaskite.

2. The foliation of the host rocks commonly wraps around or forms swirls near the broken ends of the inclusions.

3. The inclusions are typically tabular masses of thin, sheetlike dimensions, although irregularly shaped inclusions are present locally.

4. Typically, the foliation of the tabular inclusions is parallel to the borders of the inclusions and the sheetlike masses are oriented parallel to the foliation of their host rock. Some inclusions, however, lie with their foliation athwart the foliation of the host rocks, and a few do not have their foliation parallel to either their own borders or to the foliation of their host rock.

5. Commonly, inclusions have angular shapes and knife-edge contacts with their host; locally, inclusions have been partly assimilated.

6. Broken ends of tabular inclusions are commonly surrounded by a pegmatitic facies of the granite.

7. Nearly all folded inclusions have their axes parallel to the general structural trend of the host rock in which they occur.

8. The Fish Creek alaskite maintains its normal composition immediately adjacent to the dark inclusions.

Other relations not directly associated with the melanocratic gneisses but which may have bearing on their origins are:

9. Nearly all alaskitic masses of this general region contain inclusions of this type and many of the masses contain these dark gneissic inclusions nearly to the exclusion of other petrographic types.

10. Although these granitic masses are in Grenville marble, there are no marble fragments within the granites that can be interpreted unequivocally as inclusions rather than reentrants or plastic dikes.

11. No evidence of conversion of marble to these melanocratic rocks is present near any of the contacts between granitic rocks and marble in this area—even where inclusions of the dark gneisses are present in the alaskite right up to the contact between it and the marble.

12. Gabbro has intruded the Grenville marble conformably and subsequently has been altered to amphibolite and similar foliates as is shown by transitions between typical gabbros and amphibolites and pyroxene-plagioclase foliates. Thin sheets of the gneisses accompany larger masses having relict igneous textures in their interiors (Buddington, 1939, p. 13).

13. Basic volcanics have not been recognized to occur in this area; however, Osborne (1936) has reported that some do occur in Grenville rocks in Quebec.

TABLE 2

Mineral compositions of melanocratic foliates
having different modes of occurrences

	1	2	3	4	5	6	7	8	9	10	11	12
Plagioclase	45	62	31	57	56	66	52	43	62	55	62	55
Pyroxene ¹		12	4	25	12	16	16	6	24	10	3	4
Hornblende	50	19	54	8	26		24	51	3	28	10	31
Biotite	4	7	11	10	5	18	8		8	7	23	10

¹ Clinopyroxene, except in specimen No. 4, in which both hypersthene and clinopyroxene occur.

1. Amphibolitized, postalaskite, melanocratic dike rocks
2. Large irregularly shaped inclusion in alaskite
3. Tabular inclusion in alaskite; contains megascopic porphyroblasts of hornblende
4. Inclusion in central part of alaskite mass
5. Inclusion cut by a postalaskite, amphibolitized dike
6. Tabular inclusion in the alaskite (fine grained)
- 7 and 8. Inclusions in trondhjemite facies of Fish Creek mass
9. Inclusion in porphyritic granite northeast of Pope Mills
10. Inclusion in Pope Mills quartz syenite mass
- 11 and 12. Fragments in marble tectonic breccia

Petrography of the melanocratic foliates. These dark gneissic rocks are composed mainly of andesine (An_{30-45}) with clinopyroxene or hornblende or a combination of these minerals and commonly notable percentages of biotite (see table 2). A few of the inclusions in the garnet gneiss and in the alaskite near School 15 in the central part of the Fish Creek mass contain hypersthene with the clinopyroxene (4). Magnetite (to 3 percent) and apatite (to 1 percent) are the common accessory minerals. Quartz and potassium feldspars occur sporadically but invariably in subordinate amounts.

Other accessory minerals that occur sporadically are titanite, zircon and ilmenite. Myrmekite, calcite and pyrite are present in some thin sections. The andesine is zoned in all sections and has bent twinning lamellae in most. Many andesine grains show no twinning lamellae and are distinguished from quartz only with difficulty. Because of this lack of twinning, the order of zoning in the andesine has not been determined. The clinopyroxene is light green, with $2V$ approximately 60° , $ZAc = 44^\circ$, and there is marked dispersion of the axis that is

nearer the crystallographic a axis, with $r > v$ (this dispersion may indicate that the clinopyroxene is of the diopside-hedenbergite series).

All hornblende grains are pleochroic in tones of green, although those in the tectonic breccia fragments tend to be pleochroic in dark green and a greenish tan. The biotite grains are either brown or a reddish brown (Ti-rich ?).

The rocks all have similar fabrics, though notable differences are apparent in some sections. They are typically foliated and have a mosaic or sutured fabric with differing amounts of interstitial mortar. Most of the gneisses are fine to medium-grained with all minerals having relatively equal grain sizes, except for the interstitial mortar; however, a few specimens have large porphyroblasts of hornblende, and one section was seen to have large poikilitic pyroxene grains.

Andesine occurs as large grains and as interstitial mortar; quartz and potassium feldspar grains, where present, occur in a similar fashion. Some of the hornblende is apparently secondary after pyroxene, though most of it has less obvious relationships. Biotite replaces hornblende in some sections, but typically occurs as grains wrapping around grains of pyroxene or hornblende; it was probably introduced after the main period of formation of the rocks. Apatite occurs as both large and small grains. Myrmekite, calcite and pyrite are introduced or secondary constituents. Magnetite and the other accessory minerals are present as small grains in some specimens.

As can be seen in table 2, the compositions of the dark colored foliates having similar occurrences in the same host rock differ more in some cases than the compositions of those having different host rocks. No relationship between texture and composition has become apparent from the studies thus far made, and no units have been found that could be traced over appreciable distances because of their petrography. Further intensive collecting, however, may show that such relationships do exist. The only generalization to which no exception has thus far been found is: the proved igneous dikes (No. 1, table 2) do not contain pyroxene, and no inclusions cut by these dikes are free from modal pyroxene.

Theoretical considerations and conclusions. The origin of the amphibolitized melanocratic rocks that occur as tabular masses cutting the foliation of the alaskite and cutting the melanocratic inclusions within the alaskite is clear, i.e., they are postalaskite, metamorphosed basic (?) dikes. However, the other melanocratic foliates from their occurrences, mineral compositions, and textures lend themselves to many different interpretations. They could be: (1) basic differentiates of a magma; (2) fragments of intrusive dikes that injected the host

rocks and were subsequently dismembered and reconstituted; (3) the metasomatized calcium-iron-magnesium-rich members of a sequence of interbedded rocks, or (4) xenoliths, including enclaves brought up from depth.

Mafic-rich aggregations occurring in some silicic igneous masses have commonly been believed to be the result of the segregation of early crystallized material. The segregations might resemble dismembered layers, blocks or fragments engulfed by the magma during its intrusion. Perhaps some of the melanocratic inclusions in the igneous masses of this region have originated in such a manner. However, it is doubtful whether such a mode of origin can account for most of the inclusions, because: (1) Such segregates would have distinctive nonmetamorphic fabrics unless subsequently deformed, in which case they would probably have a foliation conformable to the regional trend. Many of the inclusions in the rocks of this area have their foliation athwart the trend of the regional foliation. (2) There are inclusions of similar petrographic character occurring in host rocks that have dissimilar composition. This relationship would require an extremely *ad hoc* sequence of events; the early differentiation history of the different host rocks would have to have been nearly identical, whereas the late consolidation histories would have had to have been very different. (3) Generally, the segregates and their inclosing rock have at least some mineral constituents in common. This relationship is not true in most of the occurrences in this area.

Inclusions similar in occurrence to those in this area have been reported to occur in W. Bagaskär and Pavskär, Inga, Finland (Sederholm, 1926, pp. 22 and 39-51). Sederholm interpreted the inclusions to represent two entirely different things. The inclusions in the granite at W. Bagaskär were interpreted to be dismembered mafic fillings of fissures; these fillings were formed by material that exuded from the granitic host and filled fissures in that host while the host was still in a critical state, i.e., it was in such a state of aggregation that fissures could form in it but a portion of it still retained its capacity to flow so it thus had mobility enough to permit the movements that dismembered and floated apart the mafic fissure fillings. The inclusions at the Pavskär locality were interpreted to be mafic dikes that were injected into a leptitic series that subsequently became mobile because of palingenesis *in situ*.

The writer doubts that such processes as those suggested by Sederholm account for the inclusions in any of the granitic masses of the Brier Hill area. However, the presence of faulted and deformed amphibolitized melanocratic dikes that cut the foliation of the granite

and some of the tabular melanocratic inclusions within the granite gives support to a similar idea; i.e., the inclusions represent dikes that were injected into the granitic rocks and were later metamorphosed and dismembered by movement within their host. It is impossible with the present knowledge to say how many inclusions are of this origin, but the presence of inclusions with their foliation at an angle to their own walls and to the foliation of the granitic host at least suggests that some of the inclusions are not of this origin.

The dark gneissic rocks and the granitic host may represent an interbedded sequence of calcium-iron-magnesium-rich rocks and silicic rocks that were converted into melanocratic foliates and alaskite by metasomatism or some similar process. This possibility, however, requires that the host rock was never magmatic. As is mentioned later, granitization of the host alaskite involves an extremely special sequence of processes, whereas a magmatic origin of the rock does not. As a consequence of the conclusion that the Fish Creek alaskite resulted from the consolidation of a magma, the idea that both host rock and melanocratic gneissic inclusions owe their origin to metasomatism is inapplicable. However, this does not preclude the possibility that the dark foliates were formed by such a process, so this possibility is treated below.

Similar melanocratic inclusions are widely distributed in the granitic masses of the Grenville province of the northwest Adirondacks and of eastern Canada. They generally have been considered xenoliths since the discussion regarding their occurrence by Smyth (1898, pp. 490-492). Many of the field relationships of the inclusions in this area appear to substantiate Smyth's idea for at least some of the inclusions in the granitic masses of the Brier Hill area (e.g., features 2, 4, 5, 6 and 8, as listed on page 39). For the inclusions that are xenoliths, the determination of the identity of the original rocks and the processes responsible for transforming them into the melanocratic foliates and also determination of whether they became such during the intrusion of their present host or whether they were essentially the same petrographically before its intrusion are problems.

Theoretically, many different rocks, e.g., impure dolomite, impure limestone, dolomitic shale and basic igneous rocks, including pyroclastics, flows and intrusives, could have been converted to these melanocratic rocks. This could have been accomplished by dynamic metamorphism and reconstitution, additions from thermal solutions or a combination of these processes. The processes could have occurred at any time before or during the intrusion of the host rocks and still be in accord with the field facts.

Relationships that strongly suggest that some of the rocks were derived from gabbros have been reported by Martin (1916, pp. 86-93). Buddington, on the other hand (1929, pp. 94-96 and 1934, pp. 120-122) has presented equally convincing evidence that some of them were derived from impure calcareous sediments. The presence of basic intrusives and volcanics in the Grenville series rocks of Quebec (Osborne, 1936) further suggests that some could have been derived from volcanics. Therefore, it appears quite likely that some of the dark gneissic rocks could have been derived from one type of rock, whereas others could have been derived from different rocks.

Therefore, until criteria have been established that will permit us to place the various kinds of amphibolites, pyroxene-plagioclase foliates and their variants into their proper genetic categories, all hypotheses must be considered as applicable to only local areas where field relationships and/or microscopic features are diagnostic. No absolute criteria have been found to be applicable in this area to date. The writer favors the idea that the melanocratic foliates that occur as xenoliths in the Fish Creek mass had essentially their present composition and texture before the alaskite was injected because: (1) petrographically similar inclusions are present in the marble tectonic breccia and in prealaskite granitic rocks; (2) the inclusions in the border facies and in the main mass are similar, and (3) even where inclusions of melanocratic foliates are present in the alaskite immediately adjacent to the contact with marble, there is a complete lack of marble on the marble side of the contact that is apparently in any stage of conversion toward the composition of the melanocratic foliates.

The main objections to the idea that have been suggested (Buddington, 1929, p. 94) are: (1) most of the granite masses occur wholly within marble, yet there are no inclusions of marble within the masses but only layers of pyroxene-plagioclase rocks, or amphibolite; and (2) no gabbro sills that could reasonably be considered to be the source of the melanocratic inclusions in the granite have been found to be associated with the granite masses. However, other features, as mentioned above, especially the lack of amphibolitized marble near its contacts with granite (3, p. 44) appear to make the alternative suggested idea, i.e., that the melanocratic rocks were derived from impure marble by metasomatic activity of the magma that formed the host rock, equally untenable.

Furthermore, the presence of such a foliate interbedded with the Grenville marble prior to the intrusion of the granitic magmas could account for the difference in competency required to provide the conditions favoring the phacolithic intrusion of the Fish Creek mass.

If a series of rocks, comprising marble with a few interlayers (or sills) of amphibolitic rocks, pyroxenic rocks, or some other rock having a similar competency relative to that of the marble, was subjected to folding stresses, the marble probably would flow, whereas the amphibolite, and/or rocks of similar competence, would tend to fracture. If a magma were available, it would tend to inject itself into the potential openings formed by the fracturing. The necessity for rocks that will tend to fracture in this manner during folding is practically necessary to the phacolithic concept of injection. This need could be met by a modification of the hypothesis that the dark gneissic rocks owe their origin to metasomatism of marble, i.e., that the metasomatism was effected by a retinue of fluids that preceded intrusion of the granitic magma, or by an alternative hypothesis that they were formed by metasomatism of layers unlike the marble layers at the present contacts.

The writer believes that any idea whereby the melanocratic inclusions had essentially their present compositions and textures before the folding that controlled emplacement of the alaskite magma agrees more closely with the field facts and with the theoretical considerations. Well-foliated amphibolite and pyroxene-plagioclase-foliate xenoliths

TABLE 3
Occurrences of the igneous rocks in the
Brier Hill area, New York

ROCK TYPE:	OCCURRENCE:
Basalt	dike in Fish Creek mass dikes in Grenville marble dikes in Grenville quartzite
Aplite	sills in Grenville marble dikes in Grenville quartzite
Amphibolitized melanocratic dike rock	dikes in Fish Creek mass dikes in Grenville marble (?)
Alaskite gneiss	main portion of Fish Creek mass Chippewa Creek outcrops* Brier Hill outcrop* Oak Point outcrops* Old Man Island outcrops*
Trondhjemite	border facies of the Fish Creek mass
Granitic augen gneiss	outcrops northeast of Pope Mills*
Quartz syenite gneiss	portion of Pope Mills sill*
Biotite granite	Oak Point outcrops* American Island outcrops* Point Comfort outcrops*

* Indicates major portion of mass is in an adjacent area or beneath a cover of unconsolidated material or Paleozoic sedimentary rocks.

in the alaskite with their foliation athwart the foliation of the alaskite, and xenoliths that do not have their foliation parallel to either their own borders or to the foliation of their host rock show that the melanocratic rocks had already become gneissic before they were engulfed in the magma. This conclusion is further corroborated by the presence of petrographically similar rocks as inclusions in prealaskite intrusives. Also, the fact that there are only a few rather widespread alaskitic masses of phacolithic form in the Grenville rocks of this region, whereas the Grenville sequence consists predominantly of highly folded impure marble layers similar to those layers interpreted to have been converted to the dark foliates, is apparently incompatible with the alternative view that the melanocratic foliates were formed by metasomatism of marble by activity associated with the intrusion of the alaskite magma. Therefore, it is concluded that the melanocratic foliates that occur as xenoliths within the Fish Creek alaskite mass had essentially their present composition and texture before the alaskite was injected.

IGNEOUS ROCKS

General statement. The igneous rocks and their occurrences within this area are enumerated in table 3. Granitic rocks—biotite granite, quartz syenite gneiss, granitic augen gneiss, trondhjemite and alaskite gneiss—are the only igneous rocks of areal importance. Minor dikes and sills of aplite, pegmatite, an amphibolitized melanocratic rock, and basalt, and tectonic breccia fragments with relict igneous features also occur. With the exception of the amphibolitized melanocratic dike rocks and the amphibolitized diorite (?) breccia fragments, similar petrographic types have been described from other localities within this same general region.

Age relationships. The McLear pegmatite, which has been dated as —1030 million years, has not been linked genetically with any igneous body. Therefore, only relative dating of the igneous rocks within this area is possible at present. All these rocks, except possibly the biotite granite, are post-Grenville or at least have been remobilized post-Grenville. They are generally considered to be Precambrian because they were exposed by weathering and erosion before deposition of late Cambrian (?) (Potsdam) sediments. Few definite age relationships between the different igneous rocks can be determined within the area. Relative ages and the supporting evidence are given in table 4. Suggested ages are based on the possibly fallacious assumption that similar petrographic types are of the same age (e.g., since the amphibolitized melanocratic dikes cut the alaskite gneiss of the Fish Creek mass, they are called younger than all of the masses of alaskite gneiss).

The ambiguous interrelationships of the granitic rocks that have led to much disagreement among workers in the region are also evident in table 4. Repeatedly, similar petrographic types (some from different parts of the same mass) have been given different names and some have had different relative ages assigned to them. Specimens have been collected from the different "type" areas and have been studied by the writer. Possible petrographic correlations of the different granitic rock "types" are shown on table 5.

TABLE 4

Succession of intrusions in the Brier Hill area

ROCK TYPE :	REMARKS :
Basalt	Cuts Grenville quartzite and marble and Fish Creek alaskite gneiss; nonfoliated; dikes have chill borders.
Aplite and Pegmatite	There are more than one generation of these. Latest (?) ones cut metagabbro dikes and are relatively unmetamorphosed.
Amphibolitized melanocratic dike rocks	Cuts alaskite gneiss of the Fish Creek body; is cut by pegmatites; foliated; is amphibolitized; dikes have chilled (pseudo ?) borders.
Alaskite gneiss	Dikes of similar petrography cut granitic augen gneiss, quartz syenite and biotite granite. However, all of these dikes may be peculiar shaped xenoliths.
Granitic augen gneiss	Cut by dikes of alaskite gneiss (dikes may be xenoliths) at outcrops northeast of Pope Mills.
Quartz syenite gneiss	Considered to be a facies of the granitic augen gneiss by Buddington (1939, p. 198).
Biotite granite	Cut by dikelets of alaskite (dikelets may be xenoliths); much more highly metamorphosed than adjacent alaskite gneiss; no relationships between this and granitic augen gneiss were observed.
Hypersthene-labradorite gneiss and amphibolitized diorite (?)	Occur as fragments in the Grenville marble tectonic breccia; are highly metamorphosed; are pre-last major period of hydrothermal action and last plastic deformation of the marble; age relationships to other igneous rocks are not apparent.

Though typical specimens from all these "type" areas appear to fit into three distinct petrographic categories on the basis of their inherent properties, the categories do not necessarily represent three distinct epochs of granitic intrusion. Further, all bodies composed of one certain type of granite cannot be called consanguineous on the basis of present information. Therefore, many epochs may be represented or, conversely, all three or two of the three "types" may belong to the same intrusive epoch—Buddington (1939, p. 145) has given evidence to suggest that his "Hermon type" and "Antwerp type" are only dif-

TABLE 5

Correlation of names of previous workers with petrographic types
set up in this report†

PETROGRAPHIC TYPES:	BAKER (1916)	WRIGHT (1923)	CUSHING (1925)	BUDDINGTON (1939)
Alaskite gneiss	Laurentian (1)	Mallorytown*	Laurentian (1)	Alexandria (2)
Granitic augen gneiss			Porphyritic granites (2)	Hermon (1a)
Biotite granite	Algoman (2)	Brockville*	Picton (3)	Antwerp (1b) (facies of Hermon)

* Wright considered these two types to be of the same magnetic period. He stated that he believed they can be traced laterally into each other and also into Baker's Algoman and Cushing's Laurentian.

† Numbers in parentheses indicate relative dates (1 being earliest) suggested by author cited.

ferent phases of the same intrusive epoch. Further investigation of the "types" is contemplated for the future. However, because the nomenclature of these rocks is now in this controversial state, no formal names will be assigned to the different "types" in this report.

Red color of granitic rocks. Biotite granite, alaskite gneiss, quartz syenite gneiss and some of the pegmatites are either pink or red. The color is imparted to the rocks by potassium feldspars (microcline and/or orthoclase and/or microperthite). Whether the red color is syngenetic or of later origin is a problem. To avoid repetition, the observable data related to the problem and the writer's interpretation of these data will be given here instead of under the descriptions of the individual rocks. The following features may be observed:

1. The potassium feldspar(s) of the granitic rocks of any one mass has (have) about the same color on slightly weathered surfaces, at fresh road and quarry cuts, and from well cuttings (however, no wells penetrate great thicknesses of these rocks).
2. Red and pink granitic rocks similar to those present in this area occur at moderate depths and below gray granitic rocks in the Rossie district to the south. This relationship was observed in cores from the Victoria and Coal Hill mine localities.
3. Rocks that appear to be very fresh in thin section and those that appear to be highly altered have nearly the same color.
4. The granitic rocks were probably overlain by the Potsdam sandstone. The sandstone is predominantly red in some places and nearly white in others. The red granitic rocks appear to have no preferred spatial relationships to the red versus the white Potsdam sandstone.
5. The granitic rocks have an intense red coating on their joint surfaces. This coating has no marked preference for potassium feldspars.

6. Gray granite that is older (?) than the youngest pink granite is not red on any fresh or weathered surfaces, despite the fact that its field relationships indicate that it was once overlain by the same type of red and white sandstone as that which covered nearby pink and red granitic rocks.

7. Pink granite dikes having petrography similar to the Fish Creek alaskite gneiss cut the gray granitic augen gneiss. This would be very difficult to explain by preferential secondary pigmentation of the potassium feldspars because both rocks contain about the same proportion of the same type of potassium feldspar, and both rocks have about the same porosity and permeability.

These data support the interpretation that the red color imparted to the rock by potassium feldspar(s) is syngenetic. However, the intense red coloration along joint cracks and other avenues of percolation probably resulted from the action of solutions saturated with iron oxide, possibly derived from the red Potsdam sandstone.

Biotite granite. Massive, coarse-grained, pink and gray granite with black splotches crops out in three localities within the Brier Hill area: on Oak Point, on American Island and just northeast of Point Comfort. The spatial relationships of these bodies and their petrographic similarity to masses mapped as "Brockville granite" by Wright (1923) suggest that the granite of all these outcrops may be genetically related.

No distinct intrusive relationships were observed at any of the outcrops near the contacts between the granite and Grenville series rocks, viz, on American Island and northeast of Point Comfort. However, the "Brockville granite," according to Wright (1923, p. 26), has intrusive contacts with the Grenville rocks just across the St. Lawrence River from this area. Therefore, if the biotite granites in this area are consanguineous with the "Brockville granite," they are post-Grenville. Long, narrow, tortuous bodies of alaskite gneiss occur in the biotite granite at Oak Point. These alaskite bodies are believed to be dikelets that cut the granite rather than xenoliths in the granite, because they are relatively unmetamorphosed whereas the biotite granite host is highly metamorphosed. Where rocks are so intimately related spatially, degree of metamorphism is probably a valuable criterion of relative ages. The alaskite gneiss body to which these dikelets possibly are related was exposed by erosion before Potsdam sedimentation. Therefore, the biotite granite is probably of post-Grenville, Precambrian age.

On fresh surfaces this granite is pink and gray with black splotches of biotite, which commonly have a preferred orientation, giving the rock a gneissic appearance. On weathered surfaces the pink color is less

pronounced and the biotite has been weathered out, so that weathered outcrops are dull pink or gray and have a pitted appearance. Pink potassium feldspar, colorless or white quartz and biotite comprise the major portion of the rock. White plagioclase feldspar is present in most specimens. Tourmaline and pyrite are the only other minerals that are visible megascopically in any of the specimens. Typically, the granite is coarse- or medium-grained, but not uncommonly it is fine-grained as the result of granulation. Basic schlieren and segregates, small angular xenoliths, quartz nodules and veins, simple and tourmaline-bearing granitic pegmatites, and a peculiar sillimanite-bearing inclusion are present within the granite locally.

In thin section the granite shows the following composition: quartz, 25 to 40 percent; potassium feldspar, 25 to 45 percent; plagioclase (An_{11-24}), 15 to 20 percent; biotite, 5 to 20 percent, and accessories range to 5 percent. The rock is thus a biotite granite tending toward a biotite quartz-monzonite. It has a fabric ranging from mortar to granoblastic with some porphyroclasts and some porphyroblasts made up of large microcline and oligoclase grains and flaser of quartz in a granulitic matrix of the same minerals. The matrix embays fractured porphyroblasts in some sections. All quartz has undulatory extinction and either irregular or sutured borders. The potassium feldspars, microcline and microcline microperthite, show strain shadows between crossed nicols. The plagioclase feldspar grains, all of which fall within the compositional range of oligoclase, have bent twinning lamellae, wavy extinction or both. A few of these oligoclase porphyroblasts have been corroded by microcline. Bent grains of biotite, commonly associated with magnetite and sphene, occur in aggregates that have a dimensional orientation that accents the gneissoid structure of the rock. These aggregates and other accessory minerals are in the granulated portion of the rock.

Accessories, which occur in one or more of the sections, are muscovite, hornblende, apatite, zircon, magnetite, sphene and rutile. Sphene and magnetite, intimately associated in all sections, are the main accessories. Many sections contain introduced tourmaline (schorlite) and pyrite. Secondary alteration is manifest by kaolinization of potassium feldspar, sericitization of oligoclase, chloritization of biotite and partial replacement of titanium-bearing minerals by leucoxene. Calcite is present in some weathered specimens of the granite. Some sections have a green or greenish-brown mineral associated with chlorite, replacing biotite, and along the twinning planes of some of the oligoclase. This mineral is too finely divided for definite identification with the petro-

graphic microscope; it may be an iron-rich member of the chlorite family.

Such highly metamorphosed granitoid rocks are always subject to more than one genetic interpretation. They could be metamorphosed igneous rocks or granitized sedimentary rocks. Wright, as previously mentioned, has reported that the "Brockville granite" has intrusive contacts with Grenville rocks. Biotite-rich and amphibolitic schlieren and small angular xenoliths of quartzite, biotite gneiss and amphibolite within the granite at the outcrops in this area also suggest that this is a metamorphosed igneous rock. Another rock that may also have a bearing on this question is the sillimanite-bearing rock that is closely associated with the granite on the tip of Oak Point. One contact between this sillimanite-bearing rock and the granite can be observed on the point, but other contacts are under water. Therefore, the possibility that this rock is a septum between the biotite granite and the alaskite gneiss to the south must be considered. If it is a septum, the metamorphism may have been imposed by the alaskite rather than the biotite granite.

Because the sillimanite-bearing rock is seen in contact with the biotite granite and not with the alaskite, it will be described here. On weathered surfaces, the rock appears to be an altered breccia or conglomerate. It has black rounded and angular nodules in a buff granular matrix. As seen in thin section, the nodules are composed chiefly of intimately associated biotite and sillimanite and the matrix is composed of a mosaic of quartz and microperthite with sparse grains of plagioclase. Accessory magnetite and zircon and introduced tourmaline (pleochroic in greens) are also present. The sillimanite has at least in part grown at the expense of biotite. Smith (1945, pp. 298-304) has reported a similar paragenesis for sillimanite in the contact aureole of the Whiteside granite in the Piedmont of South Carolina.

The structural relationships of these granite masses with the Grenville rocks are all obscured by cover. Average foliation measurements are shown on the map. Wright (1923, p. 30) stated that the foliation is primary. However, the rock has a marked metamorphic fabric, so it appears equally likely that the foliation is secondary. Nearly horizontal and nearly vertical joints are present at most outcrops of the granite. The horizontal ones may be sheeting joints; no well-defined areal pattern became apparent by plotting the vertical joints.

Granitic augen gneiss. Gray biotitic granitic augen gneiss crops out sparsely near the southeastern corner of the Brier Hill quadrangle. It is part of a "Hermon type" granite mass mapped by Buddington (1934, map I).

All contacts of the mass are covered within the area. However, in a new road cut on the Pope Mills-Heuvelton Road just south of this area in the Hammond quadrangle, dikes of alaskite gneiss similar to that of the Fish Creek body cut this augen gneiss, so the augen gneiss appears to be older than the Fish Creek alaskite body. This agrees with the conclusion of Buddington (1939, p. 198) who reported that "Hermon type" bodies are post-Grenville and pre-"Alexandria type" granite.

At all outcrops in this area, this rock is a granitic augen gneiss with augen of feldspar up to 10 mm. in length in a fine-grained groundmass of quartz, feldspars and biotite. The rock is gray on fresh and weathered surfaces, though locally some surfaces have sporadic limonite stains. Basic schlieren, angular amphibolitic xenoliths, quartz veins and pegmatites occur within the gneiss. Locally, the granite has structures that suggest that it was faulted and folded after it was converted into a gneiss, although the true relationships of these structures have been obscured by pegmatitization of such zones.

In thin section, the rock is seen to be composed of: microcline and microperthite, 30 to 50 percent; quartz, 20 to 50 percent; oligoclase, 5 to 20 percent; biotite, 3 to 10 percent, and accessories less than 5 percent. The accessory minerals are apatite, zircon, sphene and magnetite, and hornblende occurs in a few sections. Myrmekitization and kaolinization of the potassium feldspar, sericitization of plagioclase feldspar, chloritization of biotite, introduction of tourmaline (schorlite ?) and partial calcitization of some specimens are the main mineralogical changes that have occurred since formation of the rock. The texture is granoblastic, with porphyroblasts of the feldspars in a groundmass comprised of finely granulated quartz and feldspar grains or leaves of quartz and granulated feldspars. Biotite is restricted to the groundmass and commonly "wraps around" the porphyroblasts. Some sections have typical mortar textures, and others show notable amounts of recrystallized quartz.

Structural relations are obscured by Pleistocene deposits. All dips of foliation are steep and the strike differs greatly from place to place. Average values are shown on the geologic map. Locally, the gneiss has many nearly vertical joints; there is a concentration of strikes between N. 50° E. and N. 65° E., though the strikes of many joints fall outside this range.

Quartz syenite gneiss. Red quartz syenite, having a lineation marked by streaks of biotite, hornblende or chlorite, crops out in two areas near the south margin of the Brier Hill quadrangle east of Black Lake. This quartz syenite is part of the Popes Mills sill (Buddington,

1929, p. 83). There are also two minor masses of red syenite in the Grenville rocks near the east shore of Black Lake.

The contact between the quartz syenite and the Grenville rocks is exposed in a few places and can be located approximately in many places. The attitude of the rocks near these contact areas indicates that the main body of syenite is generally concordant and that the minor outlying bodies are in general crosscutting. With the exception of the feldspathization of included blocks of quartzite, no contact metamorphism can be attributed definitely to the quartz syenite masses. However, it is possible that these masses are responsible for all or part of the contact metamorphism attributed to the Fish Creek phacolith. Xenoliths of Grenville quartzite, a biotite gneiss and melanocratic foliates are present within the quartz syenite; the outlying syenite bodies cut Grenville rocks; therefore, the quartz syenite is post-Grenville. The upper age limit is not well established—no xenoliths of rocks similar to any of the other intrusives were observed in the quartz syenite and no xenoliths of quartz syenite were found in any of the other intrusives. However, dikes that possibly are related to the Fish Creek alaskite gneiss cut the Popes Mills sill, so the quartz syenite is tentatively held to be older than the Fish Creek alaskite. All that may be said with any degree of certainty, however, is that it is post-Grenville and probably Precambrian.

This rock has been called syenite in previous reports (e.g., Buddington, 1934, p. 69). However, Buddington very clearly stated that facies containing more than 10 percent quartz have been included with the "syenite" on his geological maps because it was impracticable to map them separately. Most of the "syenite" within this area has from 10 to 15 percent quartz, so it is all mapped as quartz syenite. The rock is composed essentially of red potassium feldspar with 10 to 15 percent quartz and about 5 percent mafic minerals. Locally, the rock is nearly monomineralic, containing only traces of quartz and mafic minerals. On fresh surfaces, the quartz syenite is red with dark streaks; on weathered surfaces, it is light pink or gray and is pitted because of the weathering out of the mafic minerals.

Intensive mashing is apparent in all thin sections of the rock. Small residual porphyroclasts that occur as augen were seen in some sections though no augen are apparent in hand specimens. Most of the augen are potassium feldspar but a few large quartz and oligoclase grains are present. The augen are in a matrix of finely granulated feldspars and quartz. The texture is cataclastic with minor recrystallization. Though no plagioclase was recognized in any of the hand specimens, some sections show that the rock has a nearly monzonitic composition

locally. Biotite or hornblende, commonly almost completely chloritized, are the main ferromagnesian minerals, though diopside grains that are probably xenocrysts occur in some sections. Accessory minerals are magnetite, sphene, apatite and zircon. Large zircon crystals are present in one of the sections studied. Chloritization of the ferromagnesian minerals, myrmekitization of microcline, sericitization of oligoclase, partial alteration of titanium rich minerals to leucoxene and introduction of calcite are the deuteric and secondary processes indicated to have occurred in some sections.

As already mentioned, the quartz syenite mass was described by Buddington as a sill. The lineation, which is particularly well shown in the small quarry just to the left of the Edwardsville-Pope Mills Road at the first quartz syenite outcrop that is seen as one goes from Edwardsville toward Pope Mills, plunges steeply to the northeast. No regular joint pattern could be established from the few observations possible at the outcrops in this area.

Alaskite gneisses. Fine-grained pink alaskite crops out in five rather widely separated localities within the Brier Hill area: (1) along Chippewa Creek just north of the southern border of the quadrangle; (2) along the St. Lawrence River south of Oak Point; (3) on Old Man Island in the St. Lawrence River; (4) about one mile west of Brier Hill and, (5) east of Black Lake. On fresh surfaces, the alaskite gneiss is pink or red; on weathered outcrops it is typically dull pink but locally is gray. Hand specimens from the different outcrops are very similar, but differences in fabric, mineral composition or both can be seen in thin sections. The differences, however, are commonly greater within one mass than between different masses. Quartz and feldspar comprise more than 98 percent of the alaskite at most outcrops. Biotite and/or magnetite are the most common accessory minerals. Most of the alaskite has a lineation because of the preferred orientation of quartz leaves and/or magnetite aggregates; commonly, it also has a foliation because of the orientation of quartz leaves, magnetite blebs or biotite. The alaskite appears massive at a few outcrops where it has undergone severe cataclasis with only minor recrystallization.

All contacts between alaskite masses and Grenville rocks, except those near the south end of the Fish Creek body, are covered by Paleozoic rocks, unconsolidated material or water. However, if the alaskites are all of the same intrusive epoch, they may be dated as the youngest granitic rocks (with the exception of minor aplites and pegmatites) in the area and older than the amphibolitized melanocratic dikes. The age relationships with the other granitic rocks have been

discussed in the sections that pertain to those rocks. Other age relationships can be observed in the Fish Creek mass, where foliated meta-gabbro dikes and unmetamorphosed basaltic dikes cut the foliation of the alaskite gneiss. The relationships indicate that alaskite was emplaced, was foliated during and/or subsequent to its emplacement, was intruded by basic magmas, was further metamorphosed as manifest by the metamorphosed condition of the gabbroid dikes, was intruded by basaltic magma and was exposed by erosion, before Potsdam sedimentation.

There are two outcrops of alaskite gneiss in the Chippewa Creek valley within the Brier Hill quadrangle—in the bed of the stream just north of Ireland Road and at the edge of the valley south of the intersection of Watson Road and Sand Street. On the basis of differences in topography between the southern part of the valley floor and the areas known to be underlain by flat-lying Paleozoic sedimentary rocks, a large portion of the valley is mapped as alaskite gneiss (see geologic map). This interpretation has been substantiated locally by well data—viz, at the bend in the road about one-quarter mile south of Brier Hill where the topography is flat east of the road and irregular west of the road; a well on the east side penetrates Paleozoic sandstone at 15 feet; two wells on the west side go through more than 90 feet of drift before penetrating “red granite.” A series of nearly continuous outcrops of alaskite between this area and the mass mapped as the “Alexandria batholith” by Cushing (1910, p. 36) and as “Mallorytown granite” by Wright (1923, p. 25) suggests that these outcrops represent a portion of the main mass.

The outcrops south of Oak Point have a similar relationship to the main mass, the nearly continuous connecting outcrops being islands and shoals in the river. It appears, however, that the outcrops on Whales Back Island and some of the nearby smaller islands are partly composed of typical injection gneiss and migmatitic rocks.

Relationships of the outcrops on Old Man Island and of the inlier west of Brier Hill are not so well defined, though it is not unlikely that they are outlying intrusions genetically related to the larger mass. The inlier west of Brier Hill may be connected to the Alexandria body in the same manner as the outcrops along Chippewa Creek—it is impossible to tell because possible linking outcrops are covered by Paleozoic rocks. However, it appears very unlikely that the Old Man Island outcrops can be so linked with the main mass because a nearly complete ring of outcrops of other Precambrian rocks encircles this outcrop area. Definite relationships between this body and rocks other than the Cambrian (?) (Theresa) sedimentary rocks are lacking.

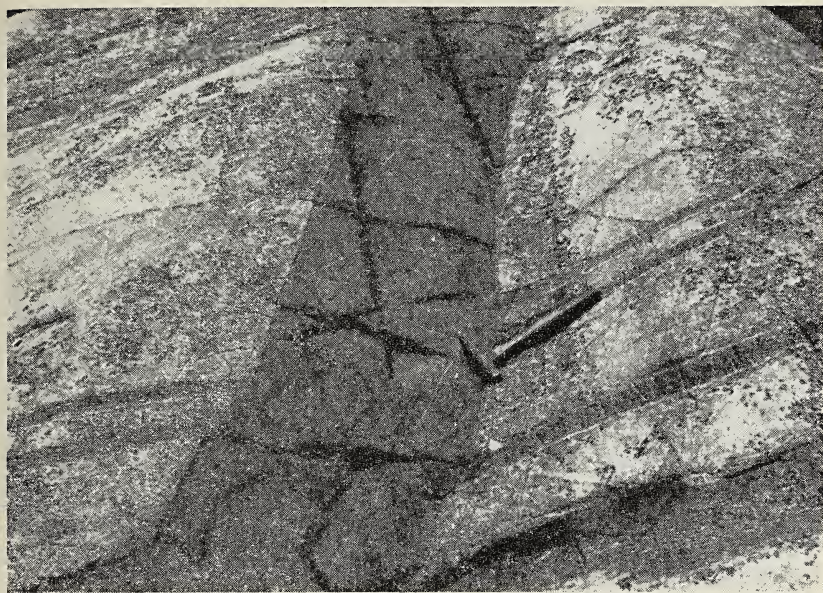
However, there are a number of angular xenoliths of quartzite, biotite gneiss and melanocratic foliates and zones of highly tourmalinized rocks within the alaskite on Old Man Island, so it is probable that the outcrops are near a contact zone.

The alaskite gneiss east of Black Lake comprises the Fish Creek mass. This mass is discussed fully at the end of this section of this paper.

The alaskite gneisses from the more northern outcrops in Chippewa Creek, the inlier west of Brier Hill, the outcrops south of Oak Point and Old Man Island are nearly identical in thin section. They are composed of: quartz, 30 to 50 percent; microcline and microcline microperthite, 25 to 50 percent; albite, 2 to 20 percent; and accessory minerals, 1 to 8 percent. The accessories are biotite, hornblende, apatite, sphene, magnetite, rutile, monazite, allanite and muscovite. Introduced tourmaline (pleochroic in greens) and pyrite and secondary kaolin, sericite, chlorite and limonite are also present. The texture is cataclastic with minor recrystallization as is manifest respectively by granulation of microcline and recrystallization of quartz. Some specimens appear to have been sheared more thoroughly than others because the feldspars of some sections are completely granulated whereas in others large feldspar grains with only broken-off corners are present. All quartz grains have undulatory extinction and either irregular or sutured borders. The alaskite gneiss from the outcrop in the stream bed of Chippewa Creek has the same composition as the rocks from the more northern outcrop but it has a coarser grain size and a higher tourmaline content. It may represent a pegmatitic facies.

Trondhjemite. At least part of the border zone of the Fish Creek body is represented by a gray or greenish-gray quartz-oligoclase rock. Rocks from this general region with similar petrography and occurrence have been described and named: bleached granite by Cushing (1916, p. 18), granodiorite by Wright (1923, p. 29), green granite by Buddington (1934, p. 87), and quartz-oligoclase gneiss by Buddington (1939, p. 170). The composition of the rock—oligoclase (An_{20-28}), 45 to 65 percent; quartz, 30 to 45 percent; and ferromagnesian minerals, less than 10 percent—is not compatible with any generally accepted definitions of granite or granodiorite. Though the name quartz-oligoclase gneiss does pertain locally, it is not generally appropriate in this area, because the rock is not gneissic at most outcrops. Therefore, the name trondhjemite (Goldschmidt, 1916, p. 76) is used. Trondhjemite was originally defined as a leucocratic, acidic plutonic rock whose essential constituents are soda-rich plagioclase (oligoclase or andesine) and quartz; potassium feldspar, if present at all, occurs

PLATE 10
Melanocratic "dikes"



A. Tabular dike cutting alaskite and melanocratic gneiss inclusions within the alaskite (near inner trough of phacolith)



B. Highly irregular mass of the amphibolitized melanocratic "dike" rock having crosscutting relationships to the alaskite and to the xenoliths within the alaskite (on east leg of Fish Creek phacolith)

PLATE 11
Melanocratic "dikes"



A. A faulted melanocratic dike. The relationships shown are difficult to harmonize with any logical chronological sequence. The sequence may have been: (1) injection of alaskite (light colored rock) into melanocratic gneiss, now represented by xenoliths (smaller dark colored masses) within the alaskite; (2) injection of melanocratic dike material (larger black mass); (3) faulting of pegmatite into the dike rock. There are other possibilities that appear to be equally as tenable. These relationships are the subject of another paper (unpublished) by the writer (same location as No. 10)



B. A closeup of junction between one of these dikes and the alaskite and a melanocratic gneiss inclusion within the alaskite that are cut by the dike (same location)

only in traces; biotite is the most important of the mafic constituents, although it is present in small quantity; in some rocks amphibole or pyroxene occur with or instead of biotite. The trondhjemite is described and discussed further on page 81.

Amphibolitized melanocratic dikes. Eighteen melanocratic dikes, ranging from a few inches to nearly 2 feet in width, cut the foliation of the Fish Creek alaskite gneiss and intersect some of the xenoliths within the alaskite. Subsequent to intrusion, these dikes have been dynamically deformed and reconstituted and have been cut by pegmatitic material. The dikes are now composed of: andesine, 45 to 55 percent; hornblende, 35 to 45 percent; opaques (magnetite and ilmenite?) to 8 percent, and minor amounts of Ti-rich biotite, apatite and zircon. No relict igneous textures are apparent in thin section, but relict chill zones are suggested because the thicker dikes have fine-grained borders and the thinner ones are fine-grained throughout. The general occurrence of the dikes suggests that they may represent spessartite dikes or some similar type of melanocratic dikes intruded during the late stages of the alaskite intrusion epoch; no corroborative evidence has been found and the presence of zircon in these rocks might be considered as prohibitive evidence.

Aplite. Tortuous dikelets of aplite cut the quartzites on Bogardus Island in the St. Lawrence River and sills of aplitic composition occur in the Grenville marble near the southern margin of the Fish Creek mass. Specimens from the Bogardus Island dikelets and from one of the sills in the marble are typical aplites; the aplitic rock from the other masses in the marble are so highly metamorphosed that their original character is questionable. If the latter really were aplite masses, it appears that there are at least two periods of aplitic intrusion in this area, i.e., pre- and post-last effective metamorphism. This is in harmony with the igneous history as indicated by major intrusions.

Hand specimens from all aplitic bodies are hololeucocratic. They are white on fresh surfaces and light gray or buff on weathered surfaces. The relatively unmetamorphosed aplite has a typical saccharoidal texture, though flow banding, outlined by quartz grains, is apparent on weathered surfaces. The metamorphosed rocks of aplitic composition are also hololeucocratic except locally where hornblende and biotite have been introduced in notable amounts. The metamorphosed types also are marked by characteristic metamorphic textures, as discussed below. Traces of muscovite are present in the aplite from Bogardus Island, and small veinlets of pyrite can be seen in some of the specimens from the unmetamorphosed sill south of the Fish Creek mass.

The compositions of these aplitic rocks, as indicated in thin section, are: quartz, 40 to 55 percent; microcline and microcline microperthite, 20 to 35 percent; albite, 5 to 25 percent, and a trace of the accessory minerals, zircon, sphene, tourmaline, biotite, muscovite and apatite. The muscovite and tourmaline occur only in the Bogardus Island aplite; biotite is present only in the metamorphosed aplitic rocks; zircon, sphene and apatite are ubiquitous. Calcite has been introduced into the sills in the marble; pyrite and hornblende have been introduced as mentioned in the megascopic descriptions. The alteration products, sericite, leucoxene and limonite, are omnipresent. The texture of the relatively unmetamorphosed aplite is panallotriomorphic. Three types of textures are apparent in thin sections of the metamorphosed aplitic rocks: (1) Augen of the feldspars are in a matrix of granulated feldspar and quartz. Where the augen are fractured, these fractures are filled with granulated material from the matrix. (2) Augen of the feldspars are in a matrix of granulated feldspars and leaves of quartz. (3) All feldspar grains are granulated; all quartz is in leaves or clusters of recrystallized quartz grains with sutured interborders. Gradations between these types are also present.

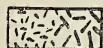
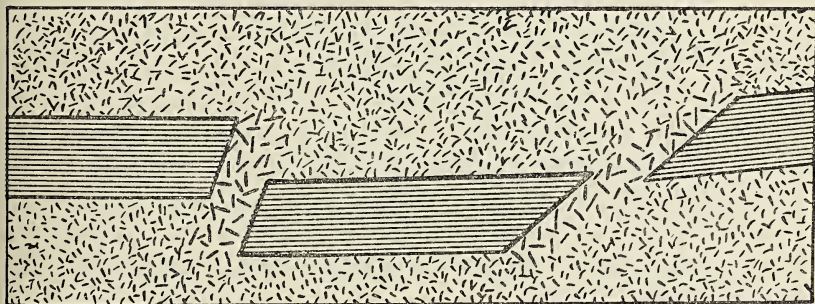
The aplitic rocks are post-Grenville, pre-Potsdam; none can be dated more definitely. Though none of these masses is structurally important, there is one structural problem that should be investigated further, i.e., the possible mechanism that could produce such marked dynamic metamorphism upon a rock within mobile marble, as is here manifest by the rocks called metamorphosed aplitic rocks.

Pegmatite. Tabular and irregular masses of pegmatite are present in nearly all Precambrian rocks of this area. The tabular masses range from a fraction of an inch to a few feet in width and are typically a few yards in length; the greatest observed dimension of any of the irregular masses is 4 feet. Many periods of pegmatite formation are represented, e.g., within the Fish Creek mass alone, there are foliated pegmatites, nonfoliated pegmatites that intersect other nonfoliated pegmatites, pegmatitic material around the broken ends of tabular xenoliths, and other pegmatites that cannot be placed definitely in any of these categories. Of particular interest are: internally zoned pegmatites (these may actually be high temperature veins), a pegmatite with associated specular hematite, the pegmatitic material associated with broken xenoliths within alaskite, and pegmatitic aggregates in the Grenville marble.

Pegmatites with internal zonal arrangement of their constituent minerals occur in the Fish Creek alaskitic gneiss near School 15 and in the biotite granite on the tip of Oak Point. Those in the Fish Creek

body differ from the simple pegmatites only by having a smoky quartz selvage. The pegmatite (high temperature vein?) on Oak Point, however, has four rather distinct zones: the central part is composed of intergrown quartz and tourmaline; relatively pure quartz makes up the next zone; quartz, with notable tourmaline, borders these two zones; this is succeeded by a thin selvage of pink microcline. These zones are all within a tortuous vein that has exposed only a 3-inch thickness. Blebs of quartz and tourmaline intergrowths like that in the central zone are present at many outcrops of the biotite granite and alaskite in the western part of this area, but have not been found to occur within this area in any of the bodies east of Black Lake.

Specular hematite occurs on joint surfaces of quartzite adjacent to a pegmatite in the central part of the largest quartzite inlier of the Point Comfort group. The hematite mineralization is restricted to a zone about 3 feet thick, immediately adjacent to the pegmatite body. Though no hematite occurs within the pegmatite itself, the spatial relationship of the mineralization and the pegmatite body strongly suggests that they are genetically related. The hematite may have been deposited by fluids that accompanied the pegmatitic fluids or it may represent a reconstitution of the iron within the quartzite, promoted by processes associated with the formation of the pegmatite. Though the latter suggestion appears more unlikely, it must be noted that locally the quartzite is rich in iron-bearing minerals (now limonite).



Fine-grained alaskite grading to
pegmatite (left to right)



Melanocratic foliate — lines indicate
trend of foliation.

Figure 3. Schematic diagram showing a broken melanocratic foliate inclusion in the alaskite gneiss. Note especially the relationship between the pegmatite and the broken ends of the inclusion.

Many tabular, foliated melanocratic xenoliths within the Fish Creek mass have been broken and the fragments pulled apart as shown on figure 3. As is shown on the figure, a pegmatitic facies of the alaskite is almost invariably present adjacent to the fractures that cut across the foliation of the melanocratic xenoliths, whereas the alaskite adjacent to the surfaces parallel to the foliation in the xenoliths is of the normal fine-grained type. The mineral composition of the pegmatite is the same as that of the typical fine-grained alaskite and the pegmatite grades into the finer-grained alaskite within a few inches. Any explanation of this type of pegmatite must be based upon consideration of all possible effects associated with the spatial relationships between the pegmatite and the xenoliths.

Two main hypotheses emerge as likely possibilities in the opinion of the writer: (1) Pegmatites may have formed near the broken ends of dismembered xenoliths because volatiles and/or highly fluid portions of the magma moved into these areas of low pressure, i.e., areas where pressure was locally reduced because of potential voids being created by fracturing of xenoliths. The volatiles could have been derived from either the magma or from the xenoliths (possibly as a byproduct of reconstitution). Such volatiles might promote formation of a larger-grained facies. (2) Pegmatites may have formed in such areas because of differences between the thermal conductivity and heat capacity values for the alaskite and for the melanocratic xenoliths, i.e., the xenolithic material has a lower thermal conductivity and a higher heat capacity than the alaskite has. This would mean that the xenoliths would retain their heat longer than the alaskite. Subsequent loss of this heat might promote slower crystallization and thus the formation of larger crystals in the alaskite adjacent to the surfaces where most of this heat was dissipated. In the foliated xenoliths, as those shown in figure 3, transfer of heat likely would be easier along the foliation than across it, so escape of heat would most likely be greater along surfaces that cut the foliation, thus accounting for the pegmatite-xenolith relations.

In the writer's opinion, cooling probably was so slow that any differential temperatures of sufficient magnitude to control grain size probably would not obtain within a mass of this size. Thus, the change in grain size probably reflects a local change in viscosity of the magma during consolidation as might occur under conditions such as those set up in "1" above.

Within the marble of the Grenville series a complete series may be found from disseminated grains of quartz and feldspar through massive aggregates of these minerals to tabular pegmatitic masses. Because

the foliation of the marble near the nodules is undisturbed in the areas he studied, Buddington (1939, p. 163) interpreted similar pegmatites as replacement pegmatites. The marble wraps around all pegmatite nodules in this area, but the marble of this area has been so severely deformed plastically that it is impossible to tell if the marble was or was not disturbed during the formation of the pegmatite.

Basic dikes and sills. Small tabular masses of basic composition that cut the Grenville series marble and quartzite and the Fish Creek alaskite gneiss body represent the youngest igneous rocks known to occur within the area. All of these masses except the very thin ones have typical diabasic fabric; the thin masses and chilled borders of the thicker masses are aphanitic.

In thin section the coarser-grained types are seen to consist of: labradorite, 45 to 60 percent; pyroxene (augite and/or pigeonite), 30 to 40 percent; olivine (commonly serpentinized), to 10 percent, and opaques, up to 8 percent. The texture is intersertal and although the rock is now holocrystalline, it looks as if it once may have had a mesostasis of glass. Pyroxene is interstitial between laths of plagioclase feldspar which have a triangular arrangement; the magnetite (?) is late. The chilled border is composed of the same minerals; sparse laths of labradorite and grains of augite and olivine are present in a very fine-grained groundmass with a microsubophitic texture. The groundmass makes up more than 90 percent of the rock. Some of the larger crystals are embayed by the groundmass material.

Igneous (?) tectonic breccia fragments. Augitic-hypersthene labradorite gneiss and amphibolitized diorite (?) occur as inclusions in the marble tectonic breccia. The petrography of these two rocks indicates parageneses unlike any other rocks found to crop out in this area. Buddington (personal communication) has found an augitic-hypersthene labradorite gneiss in the Gouverneur and Russell quadrangles, however.

The augitic-hypersthene labradorite gneiss is a linear (stengel) gneiss. It is composed of labradorite (An_{54}), 75 percent; hypersthene (Fs_{42}), 14 percent; augite, 10 percent; and minor amounts of titanium-rich biotite and ilmenite. The texture is described best as mosaic or sutured. This rock may represent a metamorphosed hypersthene gabbro or a norite.

The rock here called "amphibolitized diorite" is a melanocratic rock with quasi-phenocrysts of plagioclase feldspar, which weather in relief. In thin section, the rock is seen to be made up of large zoned crystals of andesine surrounded by a groundmass of green hornblende, bent grains of titanium-rich biotite, diopside and sphene. The large crystals

of feldspar are selectively sericitized, the inner zones being highly sericitized whereas the outer zones are not so affected.

FISH CREEK ALASKITE MASS

Introductory statement. In 1929, Buddington (1929, pp. 51-107) presented the idea that 14 alaskitic bodies in the northwestern Adirondacks are phacoliths. Only five of the masses were described in any detail; discussion pertaining to the other nine masses, mentioned as possible phacoliths on the basis of their petrography and outcrop pattern, was limited to scattered references to certain features that Buddington in his reconnaissance study found to occur within them. A more complete study of the Fish Creek mass, one of these nine bodies, was one of the main concerns of this investigation.

Geological setting. The Fish Creek mass is a steeply plunging, nearly isoclinally folded igneous body with a total outcrop area of approximately 12 square miles. The mass has a U-shaped outcrop pattern. Data from wells located between the arms of the U, i.e., wells that go through 80 to 115 feet of sandstone into marble, show that this shape is not the result of a fortuitous overlap of Potsdam sandstone but is the true expression of the shape of the mass. This body was called the Macomb granite and considered to be an outlier of the Alexandria batholith by Cushing (1916, p. 18); it was named Fish Creek Phacolith by Buddington (1929, Fig. 33, p. 52); "Fish Creek" is used in this report because the mass is on Fish Creek, whereas only a part of it is in the Town of Macomb and its southernmost part is more than 5 miles northwest of the hamlet of Macomb.

The main part of the Fish Creek mass is alaskite gneiss with local concentrations of folded melanocratic xenoliths. Trondhjemite occurs as a border facies sporadically. All intrusive contacts observed are with highly metamorphosed Grenville marble.

Structural relationships. The Fish Creek mass occupies a syncline¹ that plunges steeply toward the northeast and has a high dip toward the southeast (figure 4 and plate 12). The outcrop surface is nearly a cross section perpendicular to the axis of the mass. Therefore, the apparent thickening of the nose of the fold is an actual thickening rather than just an accident of erosion.

Structural relationships between the alaskite and Grenville rocks cannot be definitely determined in many places because most of the

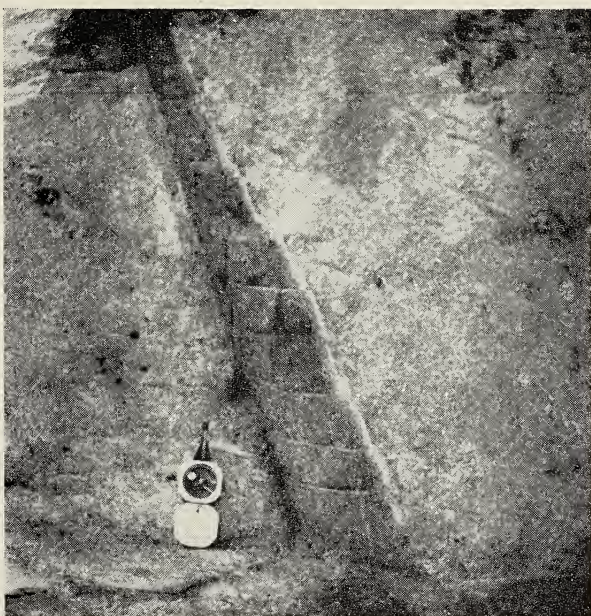
¹ Syncline is generally defined as a fold with the younger rocks toward the center of curvature. Because age relationships of different strata of the Grenville series are unknown, syncline is used here in its geometrical sense, i.e., a fold that is concave upwards.

PLATE 12

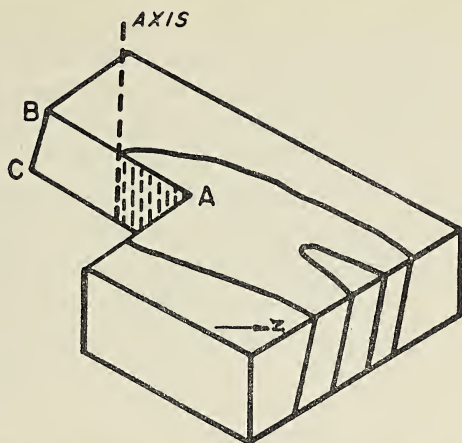
Plunge of the Fish Creek Phacolith



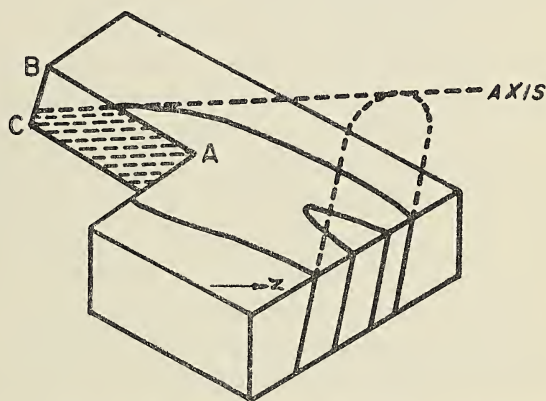
A. A horizontal surface showing folded xenoliths that have been weathered more than the alaskite host, leaving that host in relief; camera was pointed toward the east. (Near center of Fish Creek mass)



B. Intersection of foliation plane (approximately the exposed surface) and a folded xenolith. Compass is vertical; camera was pointed toward west. (Near center of Fish Creek mass)



A. An isoclinal syncline, plunging steeply to the northeast and having a high dip to the southeast.



B. An isoclinal anticline, plunging to the southwest and overturned to the northwest.

Figure 4. Different structural interpretations of the Fish Creek mass. The critical feature is the lineation, as is indicated on the ABC (foliation) plane. Buddington's (1929) interpretation (B) was based on a very brief reconnaissance study of the mass. The writer's interpretation is based on linear features such as those pictured on plate 12.

contact is covered. However, the similar orientation of minor structural features in the alaskite and in the Grenville rocks and the relationship of the two units at observable contacts suggest that the mass is at least generally concordant. The axes of nearly all minor folds in the Grenville marble and of the xenoliths in the alaskite gneiss are parallel to the lineation of the alaskite and the axial planes of most minor folds

are parallel to the trend of the foliation of the alaskite. The alaskite gneiss-Grenville series rocks contact can be observed at a few places along the southern margin of the mass. The marble is concordant to the contact except for minor divergencies. The border facies of the alaskite body is a massive trondhjemite, but the arrangement of tabular melanocratic xenoliths in the trondhjemite indicates that the igneous body is also generally concordant to the contact.

The interpretation of the structure of the body itself is indicated by foliations and lineations of the alaskite and by parameters of folded, sheetlike melanocratic inclusions in the alaskite. Foliation is marked by parallel orientation of sheetlike, melanocratic, folded xenoliths, blebs of magnetite and grains of leaf quartz in the alaskite. It is perceptible at nearly all outcrops of the Fish Creek mass, with the exception of those of the trondhjemite border facies. Although the trend of foliation of the alaskite is nearly constant over the whole body, locally the strikes and dips of the planar elements differ within short distances. Most of the abrupt local changes occur near folded and fractured xenoliths where the foliation of the alaskite commonly deviates from the areal trend and is more nearly parallel to the crenulations and broken edges of the xenoliths. The general foliation in the alaskite apparently represents an axial plane foliation and is believed to have been formed in response to major orogenic stresses. The foliation parallel to the sides and edges of folded and fractured xenoliths is thought to be due to drag effects during magmatic flowage.

In a few areas, there is a planar arrangement of hornblende and pyroxene grains. Because this is restricted to zones of noticeable assimilation, it is probably an inherited foliation, resulting from the disintegration and almost complete digestion of xenolithic material. Lineation, which is nearly constant over the whole mass, is in the plane of the foliation. It is expressed by the parallel arrangement of grains of leaf quartz and the intersections between foliation planes and folded xenoliths. The folded xenoliths are for the most part restricted to the zone tentatively designated as the axial plane of the mass on the map. The axes of the folded xenoliths are parallel to the lineation of the alaskite and their axial planes are parallel to the foliation trend. On the basis of the measurements of these foliations and lineations, the body is interpreted as an isoclinal syncline that plunges steeply to the northeast and dips at a high angle to the southeast and has the trace of its axial plane, marked by a zone of highly folded xenoliths and tabular xenoliths with their foliation athwart the foliation of the alaskite, dipping at a high angle to the southeast.

The structure of the mass may be much more complicated than indicated on the schematic diagram (figure 4A). Swamp areas and some of the covered areas possibly are underlain by Grenville marble or some other rock that is less resistant to erosion than the alaskite. They appear to be very similar to the marble area near the southern margin of the mass, and other topographically low areas proved to be underlain by less resistant Grenville rocks, e.g., the marble between the two shells of granite of the compound Gouverneur phacolith. Another kind of complication is indicated by the minor basin southeast of the core of the major fold. This feature is shown on figure 5. A possible interpretation is offered by the cross sections as is indicated in the text below the figure.

Petrography. Alaskite, that makes up the main part of the Fish Creek mass, is a fine-grained, pink, hololeucocratic gneiss. Preferred orientation of leaf quartz gives both planar and linear fabrics to

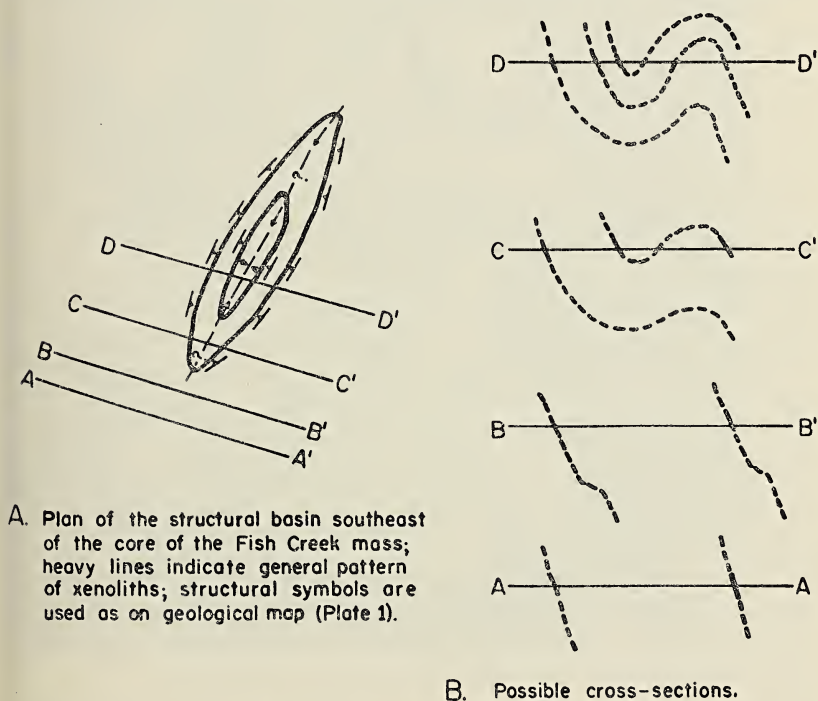


Figure 5. The structural basin southeast of the core of the Fish Creek mass. The cross sections indicate a possible interpretation of the features shown on the plan. Xenoliths folded as shown in the section c-c¹ can be seen on some surfaces perpendicular to the axis of the basin. Possibly excess heating of tabular xenoliths during the intrusion of the alaskite rendered the xenoliths plastic so that intermittent surges of magma from below or other types of movement contorted them in such a manner.

the rock. Sporadic blebs of magnetite and plates of biotite are the only accessory minerals megascopically visible. Where present, they accent the gneissosity.

From thin section studies, it is evident that the mineral composition and fabric of the alaskite gneiss differ from place to place. There appears to be a definite relationship between fabric and mineral composition, so it is believed that compositional differences are only manifestations of the relative amount of cataclasis versus recrystallization that the rocks have undergone. Two features appear to corroborate this idea; the different types grade imperceptibly into each other and the compositional differences, as indicated by their modes, are strictly mineralogical within a more or less constant chemical composition range.

TABLE 6

Modes of two heteromorphic variants of alaskite gneiss from the Fish Creek mass. Numbers indicate volumes in percentages.

	I	II
Quartz	48	50
Microline	5	22
Albite (An_{0-5})		27
Antiperthite ($Ab_{58}Mi_{42}$)		trace
Accessories ¹	trace	trace

Modal analyses of two of the heteromorphic variants of the alaskite that appear to be nearly end members in mineral composition are shown in table 6. Nearly all gradations between these end members also occur in the Fish Creek mass. Specimens containing microperthite and quartz (I) have one of two distinct fabrics—typically, they are cataclastic with or without some recrystallized quartz; perthite² and quartz in one thin section, however, show no cataclasis nor evident recrystallization. Specimens having albite and microcline with quartz (II) are believed to represent a complete reorganization of the type containing microperthite and quartz; it is suggested that the discrete grains of albite and microcline represent a complete unmixing of the perthite and segregation of the components and that the quartz, present as leaves, has been completely recrystallized. Specimens of intermediate compositions have what appear to be intermediate fabrics. The following represent a few of the diverse types from the mass:

¹ The accessory minerals, completely lacking in some specimens, are opaque mineral(s)—magnetite and possibly some ilmenite, biotite, sphene, and apatite. Secondary anatase that is closely associated with the opaque mineral(s), chlorite, kaolin, and sericite are sporadic alteration products.

² Perthitic feldspars in the Fish Creek mass have a range of composition between albite—45 to 58 percent and potassium feldspar—55 to 42 percent. *Perthite* is used here for both the *antiperthites* and the *perthites*.



PLATE 13. Panallotriomorphic quartz and microperthite perthite lamellae greatly enlarged) (X12, crossed nicols) (insert shows relationships between different



PLATE 14. Cataclastic microcline and quartz and some recrystallized quartz (X12, crossed nicols).



PLATE 15. Large cataclasts of microcline microperthite, granulated quartz and recrystallized quartz in leaves (X12, crossed nicols).



PLATE 16. Discrete grains of albite, microcline, and large leaves of quartz (X17, crossed nicols).

1. Panallotriomorphic quartz and perthite with some of the grains showing a tendency to be amoeboid; small, rounded grains of quartz occur in larger grains of the perthite and small, rounded grains of the perthite occur in larger grains of quartz; albite rims are present on the grains of perthite along quartz-perthite and perthite-perthite borders but in general are lacking along perthite-albite borders. The perthite is made up of albite approximately 58 percent and potassium feldspar approximately 42 percent.

2. Cataclastic perthite and quartz with minor albite; this rock tends to have a mortar fabric.

3. Cataclastic perthite and quartz with some recrystallized quartz.

4. Differentially granulated perthite and completely recrystallized quartz; porphyroclastic augen of perthite occur within a matrix of granulated perthite and recrystallized leaf quartz. Some thin sections have many such augen of perthite; others have only a few.

5. A mosaic of albite and microcline with large quartz leaves; a trace of perthite is present locally.

These different kinds grade imperceptibly into each other, though intermediate varieties are lacking locally between some of them.

Contact metamorphism. Both exomorphic and endomorphic effects are present near the contact of the Fish Creek mass. The Grenville rocks show evidences of reconstitution and introduction of material; the Fish Creek mass itself is notably different in grain size and composition near the contact.

Exomorphism. The exomorphism associated with the Fish Creek mass is very similar to that associated with the granitic masses in the Oxbow district as described by Agar (1923). There is no regularly zoned aureole around this mass. Contact-metamorphic minerals have several different modes of occurrence: (1) disseminated through large volumes of marble; (2) as irregular pockets both near the contact and at considerable distance from any visible intrusive contact, and (3) in completely altered bands that may represent former impure or dolomitic layers in the marble unit. Much of the marble shows no development of contact-metamorphic minerals.

Though definite age relationships between different contact-metamorphic minerals have not been recognized, there are two mineral associations that do seem to be rather widespread. They are: (1) colorless spinel and chondrodite, and (2) sphene, pyroxene (of the hedenbergite-diopside series) and scapolite. In some places, these minerals are disseminated through the marble while in others they comprise nearly 100 percent of the rock. Locally, the spinel-bearing chondrodite marbles are now opicalcites because of serpentinization of the chondrodite. The following minerals have been found to occur within this contact zone: actinolite, albite, apatite, biotite, bowlingite (?), calcite, chondrodite, cordierite (?), garnet (almandine), graphite, hornblende,

leucoxene, microcline, microperthite, myrmekite, periclase (?), phlogopite, pyrite, pyroxene (both augite and hedenbergite-diopside), pyrrhotite, quartz, scapolite (mizzonite-dipyre), serpentine, sillimanite, sphene, spinel (both green and colorless varieties), tourmaline (both blue and brown varieties) and clinozoisite. The hedenbergite-diopside, scapolite, sphene, chondrodite, quartz and different feldspars are the most common minerals other than the calcite.

Periclase was tentatively identified in thin section on the basis of its optical properties and a perfect cubic cleavage. After this tentative identification, separation of the mineral from a hand specimen was attempted. A mineral similar to the mineral called periclase in all respects, except for lack of evident cubic cleavage was isolated, X-rayed and found to be spinel. Therefore, it is not known definitely whether the mineral tentatively identified as periclase is a really colorless spinel that has a cubic cleavage or if both spinel and periclase occur in the rock.

The contact metamorphism thus far described probably represents an addition of elements from the magma as well as recrystallization and rearrangement of elements to form calcium and magnesium silicates. Among the elements probably added are boron, fluorine, chlorine and phosphorus, represented respectively by the minerals tourmaline, chondrodite, scapolite and apatite. It also appears that dedolomitization occurred during the metamorphism. No dolomite layers are present in the Grenville rocks in this area. However, Mg-rich silicates are commonly present as bands in the marble; these bands may represent former dolomite layers. Another related problem is the origin of the graphite: (1) was it formed by breaking down of the carbonate of the marble; (2) was it deposited by magmatic emanations, or (3) does it represent former carbonaceous films of organic origin? At present, graphites of known inorganic and organic origins and graphites of unknown origin from these Grenville rocks are being collected for mass-spectrochemical analyses for C-12 and C-13. The C-12:C-13 ratios may clarify the question regarding the origin of the graphite in these rocks (see Rankama, 1948).

Other petrographic types found in this area that have been attributed to exomorphism caused by similar alaskitic gneiss bodies are melanocratic foliates, quartz-oligoclase rocks and garnet gneiss (Buddington, 1939, pp. 169-172). The problems involved in determining the origin of the melanocratic foliates, which are considered by Buddington to be at least in part dependent upon contact metamorphism of Grenville marble, have been discussed. Suffice it to repeat here that many petrographic types are included and that at least some of these rocks appear to have been melanocratic foliates before intrusion of the alas-

kitic magma whereas others are post-alaskite dikes. The quartz-oligoclase rocks on the peripheries of some of the alaskite bodies have been attributed to exomorphism. They are believed here, however, to be an endomorphic phenomenon associated with the Fish Creek mass (see below).

Garnet gneiss: Garnet gneiss was found to occur in four places in and near the Fish Creek mass: (1) as a xenolith in the alaskite across the road from School 15, near the middle of the Fish Creek mass; (2) as a xenolith in the alaskite in the central part of the southern margin of the mass; (3) and (4) as thin (less than 2 feet) layers in the marble near the southern border of the Fish Creek body. The xenoliths are large (about 20 x 30 feet and 40 x 75 feet in cross-section) and irregularly shaped and contain many tabular, melanocratic inclusions which are similar in field appearance to the xenoliths in the alaskite. The thin layers, whose lateral extent is obscured by cover, appear to be intercalated layers of the predominantly marble unit.

In hand specimen, the garnet gneiss may be seen to consist of grains of dark red garnet in a matrix of feldspars and quartz. Sillimanite is visible in some specimens. Commonly the rock is gneissic because of a parallel arrangement of quartz, feldspar and bands of garnet. The garnets range from less than 1 mm. to 1 cm. in size and the grain size of the other constituents is generally between 1 and 3 mm. There appears to be a tendency for the grain size of the majority of garnet grains to vary directly as the size of the quartz and feldspar grains.

In thin section, typical garnet gneiss is seen to be composed of almandine, sillimanite, microperthite, andesine, quartz and biotite, with minor green spinel, sphene, myrmekite, zircon, apatite, sericite and opaque minerals. Locally, sillimanite is absent. The garnets are generally skeletal and some appear to have helicitic structures. Sillimanite apparently formed during the late stages of and also after the garnet had formed—it occurs as inclusions in the peripheral parts of some of the garnet grains and also wraps around garnet grains, but it is never found as inclusions in the interior portions of any but the very small garnet grains. Biotite is truncated by the garnet grains and it is noticeably bent and crushed where present between grains of garnet; in some places it also wraps around the garnets. The quartz and feldspars have been deformed markedly as is evidenced by highly contorted twinning lamellae of plagioclase grains and the overall sutured or mortar fabrics. In some sections the garnet and quartz appear to have had an antipathy for each other—quartz is not found adjacent to garnet; even the quartz grains included in the skeletal garnets have

feldspar between them and the garnet. The other minerals appear to be ubiquitous.

The origin of similar garnet gneiss in this general region has been a subject of great interest since Martin's (1916, pp. 24-40) discussion of different possible origins for the garnet gneiss in the Canton quadrangle. Martin found three distinct modes of occurrence: (1) a large folded mass of garnet gneiss (2,600 feet thick and exposed long dimension of 6 miles); (2) long narrow bands along the periphery of a granite body, and (3) small lenses and layers interbedded with typical Grenville sediments. He concluded that the garnet gneiss resulted from metamorphism of siliceous-aluminous sediments. He believed that the garnet gneiss associated with the periphery of the granite mass was merely the result of fortuitous intrusion of magma into a garnet gneiss bed rather than contact metamorphism of marble because of the failure of the garnet gneiss to form an uninterrupted aureole around the granite body, the presence of parallel belts of garnet gneiss with layers of unchanged marble between them, and the petrographic similarity of this garnet gneiss and that found interbedded with Grenville beds not near any visible granite contact.

Buddington (1929, pp. 96-105) reviewed the objective data regarding the garnet gneiss and concluded that that which occurs around the peripheries of the alaskitic bodies in marble originated as a consequence of interaction between a portion of granitic magma enriched in hyperfusibles and/or thermal solutions and an earlier formed amphibolitic facies (which was formed by prior contact metasomatism of marble). He rejected the interpretation of Martin in favor of this idea because: (1) garnet gneiss occurs along at least part of the contacts of 11 different granite bodies that intruded Grenville marble and (2) there is a lack of alumino-siliceous beds intercalated in the Grenville marble suitable to form so much garnet gneiss. The writer believes that, in attempting to formulate one general hypothesis of origin for all of the garnet gneiss in this general region, too much emphasis has been placed on showing similarities between different occurrences while dissimilarities have been more or less ignored.

Many well-established examples of similar petrographic types that have been derived from different original rocks by diverse processes are well known, e.g., amphibolites derived from metamorphism of impure limestone (Adams and Barlow, 1910, pp. 87-125), and those derived from gabbro dikes (Teall, 1888, plates XIX-1 through XXI-1). Although it may be that all the different occurrences of garnet gneiss in this region that are spatially associated with alaskitic intrusions in marble did have the same genesis, it is also possible that some of this

garnet gneiss was derived from one type of rock and some of it from other types and that different processes were involved. The presence of similar minerals in contact aureoles around alaskitic bodies that intruded aluminous gneisses (Smyth and Buddington, 1926, p. 88) and the occurrence of garnet gneiss intercalated in Grenville sediments and not near any visible granite contact (Martin, 1916, pp. 25-26), considered along with the evidence cited by Buddington (*op. cit.*), strongly suggest that the garnet gneiss is of more than one mode of origin.

As just stated, garnet gneiss in this area occurs as thin layers in the marble south of the Fish Creek mass and as xenoliths within the Fish Creek mass. Only two thin layers of unknown lateral extent were found to occur in the marble. These layers are believed to represent metamorphosed aluminous sediments because their mineral composition and occurrence as intercalated bands in the marble may be readily explained by this interpretation. The nature of metamorphism responsible for the formation of the garnet gneiss is not known, but the presence of helicitic garnets suggests that this formation was at least in part coincident with kinetic metamorphism.

The garnet gneiss xenoliths have extremely complex field relations and appear to have complicated histories. Whether the garnet gneiss had essentially the same composition before being incorporated in the alaskite host or whether it gained its present identity because of processes associated with its incorporation into the magma is not known. The presence of many pegmatites in the garnet gneiss suggests that it was attacked by magmatic solutions. However no marked changes can be detected adjacent to such pegmatites (other than local rendering mobile of the garnet gneiss) and this weakens any hypothesis that regards solutions accompanying the pegmatites as responsible for the changes. The main constituents of the garnet gneiss, e.g., silicon, aluminum, iron and oxygen, as indicated by the mineral composition of the rock, could represent primary constituents of the rock from which the garnet gneiss was derived or they could have been added in part from magmatic sources. Because of notable differences in aluminum content from place to place in these garnet gneiss xenoliths, the writer favors the idea that this garnet gneiss was derived essentially by simple reconstitution of aluminous-siliceous sedimentary rocks; such differences in aluminum content are very common in argillaceous sediments. On the other hand, such differences would involve extremely selective aluminum introduction if the garnet gneiss were considered to be the result of introduction of magmatic aluminum into an iron-rich, calcareous rock. Admittedly, such selective introduction

of aluminum probably can occur; however, it seems a less likely resolution of the problem in the light of some of the evidence. There is one obvious feature associated with the occurrence of garnet gneiss as a xenolith in the central part of the Fish Creek mass, not described from other areas, that may be significant in determining the origin of the garnet gneiss at this place. As shown on figure 6, there is a concentration of garnets and biotite immediately adjacent to the melanocratic inclusions in the garnet gneiss, and a depletion of garnets in a zone between this selvage around the inclusions and the "normal" garnet

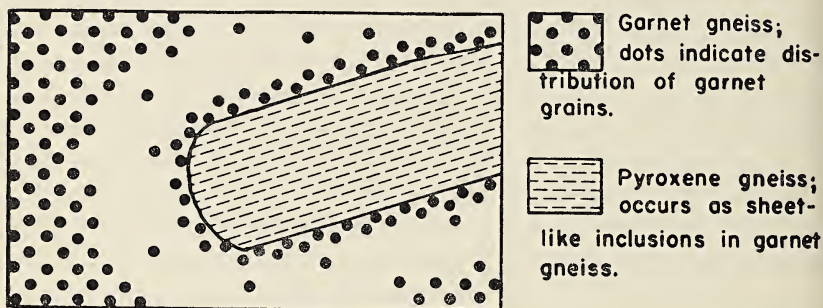


Figure 6. Schematic diagram showing relative zonal concentration of garnet around a melanocratic inclusion in garnet gneiss. Scale = 1:3

gneiss. Also, the "normal" garnet gneiss near the inclusions showing this relationship has no sillimanite. This feature suggests the possibility that the supply of aluminum limited the quantity of garnet formed at this occurrence. If such is the case, the following idea may pertain. The aluminum in the portion of the rock that became "normal" garnet gneiss utilized disseminated iron and silica in the rock to form garnet; aluminum near iron-rich inclusions migrated toward the iron of the inclusions forming the garnet selvage on the inclusions. This migration of aluminum depleted the aluminum content of the areas adjacent to the selvage, thus inhibiting further growth of garnet in these zones. Therefore, garnet formation was limited by the amount of aluminum available. That sillimanite is lacking in the garnet gneiss of this type is corroborative. In other places, however, garnet gneiss of similar occurrence (as xenoliths in the alaskite) appears to have had an excess of aluminum; this excess is indicated by a notable percentage of sillimanite in the rock. Therefore, in these places, aluminum content could not have controlled the amount of garnet that could be formed. The difference in aluminum content from place to place certainly is not a diagnostic criterion for one or the other idea. However, the writer believes it favors the idea that the garnet gneiss was derived by reconstitution of heterogeneous aluminous sediments rather than

the idea that the aluminum was selectively added from magmatic solutions.

Possible endomorphic origin of trondhjemite. The alaskite of the Fish Creek mass grades into a trondhjemite near at least part of its contact with the country rocks. The trondhjemite zone, which ranges from a few feet up to 500 yards in width, is concluded to represent a portion of the magma contaminated by the calcareous country rock.

In hand specimen, the trondhjemite is typically dark gray or greenish gray, medium-grained and massive. It is composed chiefly of plagioclase feldspar and quartz with minor biotite and/or hornblende. On fresh surfaces, the rock is dark gray or greenish-gray; on weathered surfaces, it is light gray and typically the feldspar is weathered out, leaving the quartz in relief.

In thin section, the trondhjemite may be seen to have the composition: plagioclase feldspar (An_{27-32}), 45 to 65 percent; quartz, 20 to 40 percent; biotite up to 8 percent; hornblende, up to 4 percent, and accessories, less than 2 percent. Typically, the rock has a mortar texture. The oligoclase-andesine is present as large and small grains which along with quartz make up the matrix. All the plagioclase is zoned and has bent twinning lamellae and most of the grains are antiperthitic. Quartz, most of which is in the matrix, has undulatory extinction. Biotite occurs with or without hornblende and both are commonly chloritized. Diopside-hedenbergite occurs sporadically. Large apatite grains, zircon and ilmenite with included lamellae of magnetite are the common accessory minerals. Partly myrmekitized microcline-microperthite is present in small percentages in some sections. Pyrite cubes, limonitized in part, and epidote have been introduced locally, and calcite is present locally near the trondhjemite-marble contact zone.

The origin of the trondhjemite is puzzling. The trondhjemite appears to occur as a contact facies of the Fish Creek fine-grained, pink alaskite gneiss body, as it grades laterally into the alaskite. Facts that may help to explain the origin of the trondhjemite are:

1. Compared to the alaskite gneiss (S.G.-2.58-2.62) of the main mass, the trondhjemite (S.G.-2.65-2.69) has:

- a. less quartz
- b. more plagioclase feldspar (which is more calcic)
- c. practically no potassium feldspar
- d. a slightly greater mafic mineral content
- e. a notable amount of apatite

This indicates chemically that the trondhjemite has a lower silica and potassium content and a slightly higher aluminum, magnesium, iron, calcium and phosphorus content than the alaskite.

2. Compared to the melanocratic foliates, the trondhjemite has:

- a. much more quartz
- b. a more sodic plagioclase feldspar
- c. a much lower mafic mineral content

This indicates chemically that the trondhjemite has a higher silica, aluminum, sodium, potassium and phosphorus content and a lower magnesium, calcium and iron content than the melanocratic foliates.

3. The trondhjemite is coarser grained than the alaskite.

4. Melanocratic foliated inclusions and schlieren are present in the trondhjemite and the alaskite gneiss; no apparent gradation toward trondhjemite is present between these inclusions and the host rock of either type.

5. Ilmenite with included lamellae of magnetite are present in the trondhjemite.

6. The plagioclase in the trondhjemite is commonly antiperthitic.

Buddington (1939, pp. 170-171) considered the removal of potassium, necessary if the trondhjemite is considered to have been derived from the same magma as the alaskite, to be most difficult to account for. Consequently, he concluded that the quartz-oligoclase rock was not derived from the alaskite magma. He advanced the hypothesis that it probably represents an amphibolitic rock that was modified by thermal solutions given off by the alaskite magma. The possibility that the trondhjemite represents a portion of the alaskite magma that was contaminated by assimilation of adjacent impure marble appeals to the writer.

Such contamination would account readily for the higher calcium, magnesium and iron content in the border facies than in the main part of the mass. The addition of these elements also could be indirectly responsible for the lower potassium and silica content. The portion of the magma to which the calcium, magnesium and iron was added would be more basic in composition than the uncontaminated alaskite magma. This more basic portion of the magma probably would be consolidated at a higher temperature than the uncontaminated alaskitic magma of the main mass. Therefore, rock from the facies formed from this essentially more basic portion of the magma might be expected to have a lower potassium and silica content than that that resulted from consolidation of the uncontaminated alaskite magma. That is, introduction of the calcium would initiate formation of a greater quantity of more calcic plagioclase, possibly with a consequent depletion of aluminum to the extent that there would not be sufficient aluminum remaining for the formation of potassium-feldspar and thus promoting migration of the potassium to a zone where it could be utilized (the relative abundance of biotite in the contact zone rocks and the fact that the Fish Creek alaskite is a relatively high-potassium granite may be indicative of such a migration) and the lower silica content would be resolved on merely a residual open space volume availability basis.

Assimilation of country rocks also might account for the presence of early formed biotite in the rock; if the marble had a water content, addition of this water to the magma might induce early formation of biotite. Further, the effect of the contamination on the consolidation temperature might account for the antiperthitic and magnetic-ilmenite intergrowths. The higher phosphorus content of the trondhjemite, as indicated by the relatively high apatite content, can be explained by the assimilation of impure marble or by the introduction of magmatic fluids containing phosphorus. The coarser grain size of this border facies may have been dependent upon a relative lowering of the viscosity of the magma by the presence of gases. Such gases could have been derived from the magma or from a partial breakdown of the country rock, or merely by the fact that the contaminated portion of the magma would have been in essence a more basic magma. Though no unequivocal genetic significance has been attached to ilmenite-magnetic mixtures, most deposits having this mixture have been interpreted as magmatic and all have been called high-temperature deposits.

Theoretically, antiperthite may be formed by replacement, simultaneous crystallization of potassium feldspar and plagioclase feldspar, or exsolution of an originally homogeneous mixture of the two feldspars. The constant proportion between the feldspars, the rectilinear shape of the included potassium feldspar as shown in thin section and the lack of any potassium feldspar replacement features seem to preclude the replacement origin. Simultaneous crystallization or crystallization as an homogeneous mixture might be accounted for in any of the following ways:

1. The trondhjemite has been found to occur only in the contact zones between alaskite and marble; such zones are commonly believed to be subject to more rapid cooling than the main mass. Simultaneous crystallization is likely to occur in such zones. The potassium feldspar-plagioclase feldspar ratio could be accounted for by the earlier removal of part of the potassium to form biotite, as mentioned above.

2. The crystallization of the components as a homogeneous mixture also might be expected to occur in zones of rapid cooling. At high temperatures, plagioclase feldspar can hold more potassium in solution than it can in its "normal" crystallization temperature range (see Bowen and Tuttle, 1950, p. 501); rapid cooling might preserve such a disequilibrium phase, and subsequent exsolution would yield the antiperthite.

3. Assuming constant pressure, the temperature of crystallization of a given mineral from a magma is mainly dependent upon concen-

tration of component elements. Thus, in silica-saturated magma, the crystallization of potassium feldspar is mainly controlled by the relative concentration of potassium and aluminum. A disproportionate removal of these constituents early in the crystallization history of the magma might substantially affect the temperature at which the potassium feldspar would crystallize. In the formation of biotite, such a disproportionate removal of these two elements occurs (the ratio $\text{Al}_2\text{O}_3:\text{K}_2\text{O}$ is greater than unity in biotite). It appears that this would lower rather than raise the temperature at which potassium feldspar would crystallize, but possibly, because of effects in complex silicate melts that are not yet well understood, it could move the reaction in the other direction. If it did, this might account for nearly simultaneous crystallization of the two feldspars.

The presence of petrographically similar foliated melanocratic xenoliths in both the alaskite gneiss and the trondhjemite with no perceptible gradation toward trondhjemite in either must be explained also. This fact is apparently incompatible with Buddington's thesis—it is not incompatible with the idea suggested here.

Xenoliths. Dark gray and black gneisses that comprise several different petrographic types occur as sheetlike and irregular shaped inclusions in the Fish Creek alaskite body. There are also sparse inclusions of garnetiferous gneiss and quartzite. The origins of these inclusions are discussed in different parts of the paper (garnet gneiss, pp. 96–103, and melanocratic gneisses, pp. 37–50). Some of the field relationships of the melanocratic inclusions are reiterated briefly here because they have bearing on the question of whether the alaskite is magmatic or not and on the mode of emplacement of the Fish Creek mass.

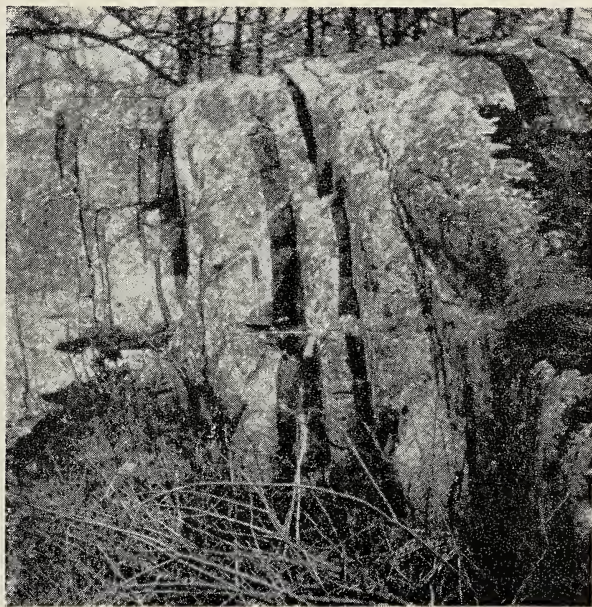
It is possible to get a clear, three dimensional concept of the form and occurrence of these inclusions because of the abundance of both horizontal and vertical exposures. They are thin sheets that are typically parallel to the foliation of the alaskite and generally have an internal gneissosity parallel to their margins. The sheets range from less than an inch to a few feet in thickness, are up to many rods in length and appear to have extensions in depth comparable to their length along the strike. Most of these sheets have very sharp contacts with the alaskite, although locally they are partially assimilated. The alaskite immediately adjacent to those with sharp borders is identical in composition to that of nearby xenolith-free alaskite; xenocrysts of hornblende and/or pyroxene are common in the alaskite near assimilated xenoliths. Though even the thinnest bands may be traced over great distances along the strike, it is only rarely that they are

PLATE 17

Dimensions of xenoliths



A. Horizontal outcrop surface (near center of Fish Creek mass)



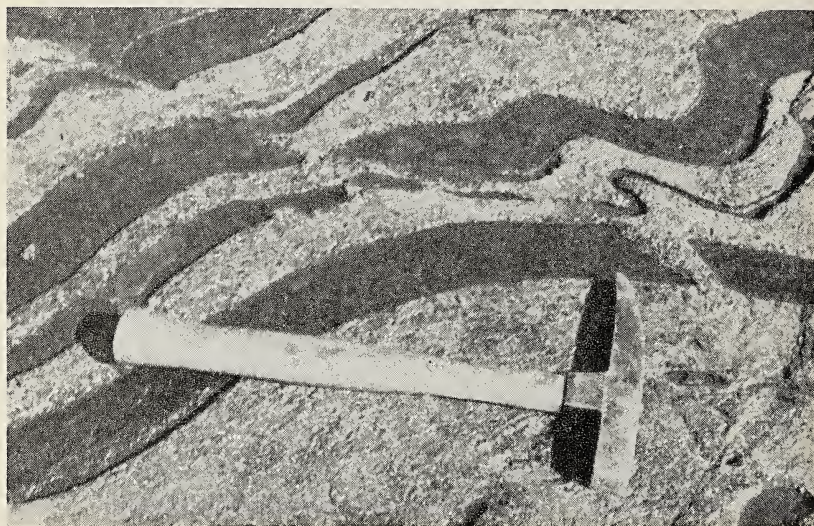
B. Vertical exposure nearly perpendicular to strike of xenoliths (on east leg of phacolith)

PLATE 18

Contorted and fractured xenoliths



A. Folded xenolith in axial plane zone of the Fish Creek phacolith

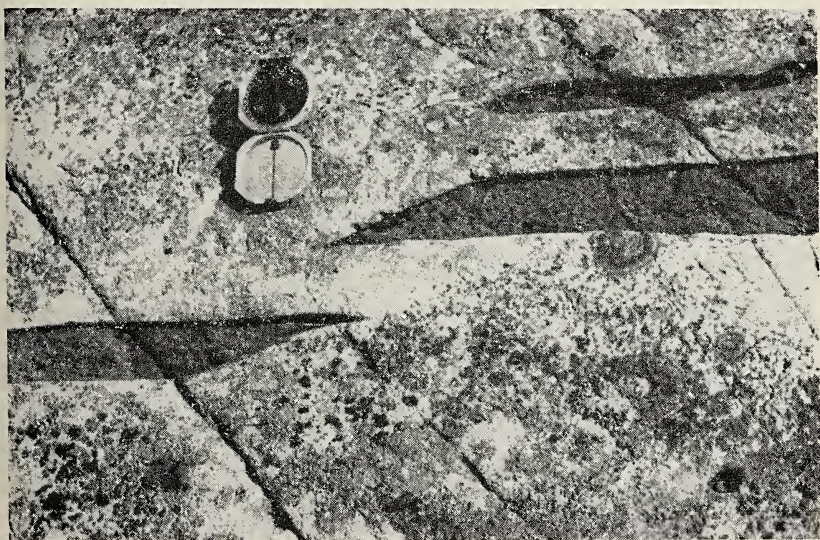


B. Folded and fractured xenoliths. Note difference in amplitude between folds in xenoliths having different thicknesses. Note also how the folded xenoliths are also fractured. (Near School 9 on west side of phacolith)

PLATE 19
Fractured xenoliths



A. Note how the two faulted xenoliths had opposite relative movements after original movement along fault surfaces (near inner nose of phacolith)



B. Closeup of xenolith shown in top of A. Note how the xenolith was first faulted in such a manner that extension resulted whereas subsequent movement—after separation—resulted in relative shortening

continuous for over a few feet. Generally, they are broken and alaskite fills the intervening spaces. Whereas most of the terminations are angular, some show evidences of having been corroded by the magma. Some bands, because they are members of distinctive sequences of bands, may be traced for great distances along the strike, even though they have been broken and floated apart; others lose their identity within short distances.

At some outcrops, individual, highly contorted sheetlike xenoliths occur between other sheetlike xenoliths that are nearly straight or but slightly bent. Typically, the relatively uncontorted sheets are fractured at closer intervals than the contorted ones. Also, the highly folded xenoliths are typically thinner than the fractured and/or slightly folded ones suggesting that heat may have been the controlling factor, i.e., the thinner ones may have been heated through and thus rendered plastic, whereas the thicker ones may have been heated less completely, thus retaining a certain degree of rigidity. Locally, highly contorted sheets that are also highly fractured occur; this, considered in conjunction with the above, suggests that the relative rigidity of the xenoliths differed both spatially and temporally during the intrusion of the alaskite, i.e., at one time one xenolith may have been relatively plastic and another relatively rigid, whereas at another time, the relationships may have been reversed. The presence of contorted sheets between relatively unfolded sheets also suggests that there probably was a notable freedom of movement among the different layers. This freedom of movement is further suggested by other structural relationships (see plate 19-A); as is apparent, shortening was the result of the relative movements involving the thinner xenolith, after the fracturing and separation of the broken ends, whereas lengthening was the result of the relative movements involving the thicker xenolith, after it was fractured.

The xenoliths of the axial plane zone are of special interest. As mentioned above, nearly all of the xenolithic sheets have their own foliation parallel to their margins, and the sheets themselves are parallel to the foliation of the alaskite. Many of the xenoliths along the trace of the axial plane of the major fold, however, do not follow this habit. Compared to the marked regularity of the xenolithic pattern at most occurrences, the arrangement in the axial zone is quite haphazard. Though most of the xenoliths have their foliation parallel to their long dimensions, others have their foliation more nearly parallel to their short dimensions. Both types are commonly folded, and the ones with their foliation across their long dimensions show thickening of their noses similar to that of the major fold. Not uncommonly,

tongues of alaskite have penetrated these latter xenoliths along their foliation planes. Many xenoliths have their foliation athwart the foliation of the alaskite in this zone, and locally, adjacent xenoliths do not even approach parallelism of either their shapes or of their internal foliations. The only regularities apparent in the zone are the general parallelism of the axial planes of folded xenoliths and the general foliation of the alaskite and the general parallelism of the axes of the folded xenoliths and the lineation of the alaskite. One other notable feature that is evident in some places near this axial zone is the shape orientation of irregularly shaped xenoliths; many have their long dimension parallel to the foliation of the alaskite.

Magmatic origin of the alaskite. No glass of alaskitic composition has been found to occur associated with the Fish Creek mass, so it cannot be stated unequivocally that the alaskite ever existed as a magma. However, the body is believed to have resulted from the consolidation of a magma rather than through granitization of sedimentary rocks because all features associated with it can be explained readily on the hypothesis of magmatic origin, whereas a sequence of rather special events must be invoked to explain all the features under the granitization hypothesis. Features that must be explained by any hypothesis of origin for the alaskite are:

1. The ratio of the thickness of the nose to the thickness of the limbs is greater for the folded alaskite body than the ratio of these same parameters of folds involving Grenville rocks.
2. Structural features such as that shown in plate 11 could only result from movements in a very mobile material.
3. The foliation wraps around some of the inclusions.
4. Tabular inclusions within the alaskite typically are oriented parallel to the foliation of the alaskite host.
5. Strike and dips of linear and planar elements of the alaskite gneiss differ within short distances locally.
6. Threadlike fingers of alaskite locally penetrate inclusions along their foliation planes.
7. In some places, tabular inclusions that are highly folded lie between those that are relatively uncontorted.
8. Some inclusions lie with their foliation athwart the foliation of the alaskite.
9. A few inclusions do not have their foliation parallel to either their own borders or to the foliation of the alaskite.
10. Most inclusions have angular shapes.
11. Most contacts between inclusions and the alaskite host are "knife edge" in sharpness; this is evident in both hand specimens and thin sections.
12. Alaskite that is apparently undeformed, alaskite that has a marked cataclastic texture, alaskite that has been recrystallized and alaskites with intermediate textures occur with no apparent systematic spatial arrangement within the mass.

13. The alaskite contains a notable percentage of perthite composed of nearly equal amounts of potassium and sodium feldspar (K-feldspar—55 to 42 percent; Na-feldspar—45 to 58 percent) and/or discrete grains of albite and microcline.
14. Contact metamorphism, both endomorphism and exomorphism, occurs.
15. The alaskite mass has some crosscutting relationships at its contact.
16. Pegmatite and aplite bodies show a peripheral association to the alaskite.
17. At least 14 bodies of this type, i.e., composed of alaskite and structurally restricted to the crests or troughs of folds, are present in this region.

Different ideas concerning the origin of the alaskite can be resolved into two main hypotheses: (1) the body resulted through transformation, in the solid state, of preexisting rocks—granitization; or (2) the body resulted from consolidation of mobile rock matter that consisted in part of a liquid phase with the composition of a silicate melt—a magmatic origin. Considering the field facts in the light of these two hypotheses, it is evident that none of the evidence is out of harmony with a magmatic origin for the alaskite whereas some features do seem to be out of accord with the granulitization hypothesis. The first seven features listed indicate that the host alaskite was mobile during one period of its formation. This mobility could be accounted for by a magma or by the granulitization of a rock that was mobile before replacement. The fact that the ratio of the thickness of the nose to the thickness of the limbs is greater for the folded alaskite body than the ratio of these parameters of folds involving Grenville marble (1), however, necessitates the granulitization of a rock that was even more mobile than the marble during the folding.

No rocks of the Grenville series that appear to have been more mobile under deforming forces than the marble have been found to occur within this general region. On the other hand, a magma probably would have had the requisite mobility to account for this feature. The fact that highly contorted inclusions lie between relatively uncontorted inclusions (7) indicates that there was great freedom of movement among the different inclusions and that very restricted regions were affected by movements that were out of harmony with the major forces. The movements indicated appear to have been similar to those found in flowing fluids. The presence of inclusions that lie with their foliation athwart the foliation of the alaskite (8) imposes the further condition that there were at least two periods of foliation formation; this could be accounted for easily under the magmatic hypothesis by intrusion of a magma, that solidified to a gneiss, into a foliated sequence of rocks. If the alaskite was formed by granulitization, however, it would necessitate at least two periods of metamorphism, the latter of which would have had to have been strong enough to initiate a new or differ-

ent foliation in one member and yet not strong enough to efface a previously formed foliation in the other member.

It might be suggested that this set of conditions is not necessary because the inclusions might represent dismembered sills and dikes rather than foliated sedimentary rocks; if this were true, however, the foliations of the inclusions would be relict igneous foliation and typically would be parallel to the borders of the tabular sheets; the presence of inclusions having their foliation at an angle to their margins and also at an angle to the foliation of the alaskite (9) precludes this origin for at least some of the inclusions and thus some relationships are present that do require at least two periods of metamorphism. This especially complicates any suggestion that the mass resulted from granitization because it is the alaskite that has an axial plane foliation whereas the foliations of the xenoliths commonly deviate from this trend. Furthermore, consideration of the present degree of preferred orientation of constituent minerals in the host alaskite and in the included rocks suggests that the included rocks are more susceptible to induced foliation than is the alaskite.

Concerning the fabrics of the alaskite (12), none has a fabric that can be called unequivocally protoclastic. However, the presence of the different fabrics with no obvious systematic spatial arrangement within the mass may suggest that the deformation took place during consolidation of an at least partly mobile material. Under this interpretation, the cataclastic rocks might represent the results of deformation of consolidated portions of the magma; the recrystallized rocks, consolidated portions of the magma that was deformed in the presence of fluids or while it was hot, the fluids or higher temperature promoting recrystallization; the alaskite having a panallotriomorphic fabric without traces of either cataclasis or recrystallization, a portion of the magma that consolidated in zones sheltered from deformation, or a portion of the magma that consolidated after the main deformation; and the rocks having intermediate textures, intermediate conditions. The relative time of consolidation of the magma with respect to the period of effective deformation would have been the only control, and it is therefore only necessary to assume that different parts of the magma consolidated and cooled at different times from other parts. If, on the other hand, the fabrics are considered to represent deformation of solid rock, very localized forces of notably different magnitudes would be necessary to account for the differences. Field evidence appears to corroborate the interpretation that the deformation was during the period of consolidation; although most of the foliation appears to be an axial plane foliation, locally, there are swirls around the ends of

inclusions, and in some places, the foliation faithfully follows all contortions of folded inclusions. Such heterogeneity of fabric is in accord with the interpretation presented here; it could be accounted for by deformation in the solid state only by invoking ad hoc conditions. Thus, it is concluded that some of the foliations in the alaskite mass represent deformation during the cooling cycle of the magma whereas others may represent primary foliations. Deformed post-alaskite dikes within the mass suggest, however, that some of the fabrics may even represent later modifications.

If it is supposed that the perthite in the Fish Creek alaskite was formed by unmixing of an originally homogeneous alkali feldspar rather than by replacement or some other process(es), then the presence of perthite consisting of nearly equal amounts of potassium feldspar and sodium feldspar (13) indicates that the alaskite consolidated at a temperature of at least 650°C . (Bowen and Tuttle, 1950, pp. 501-502 and 510-511). The extremely low calcium content of the alaskite, and comparison of the features of the perthites in the alaskite with features commonly shown by structures known to have formed by unmixing from originally homogeneous solids (e.g., pearlitic structures in some alloys) warrant this supposition, in the writer's opinion. The alaskite made up of discrete grains of microcline and albite is interpreted as the result of unmixing carried to its ultimate limit, i.e., complete elimination of one feldspar from the other. This unmixing of a once homogeneous alkali feldspar into perthite and locally into discrete grains of albite and microcline may have been promoted by prolonged heating below the temperature of stability of the homogeneous feldspar (Bowen and Tuttle, 1950), by stress (Phemister, 1926, p. 25; Larsen, 1938; Buddington, 1939, p. 329; Chayes, 1950), by slow cooling (Chayes, 1950, p. 293) or possibly by a combination of processes. It appears likely in the light of the suggested mode of emplacement of the mass and of post-emplacement events that the alaskite was in a zone where prolonged heating or slow cooling would have obtained and also that it was affected by tectonic stress(es) both during and after emplacement. That the feldspar was at or near 650°C . at one time in its evolution is strong evidence in favor of a magmatic origin for the Fish Creek alaskite, in the writers' opinion.

The shapes and contacts of the xenoliths (10 and 11), the contact metamorphism (14), crosscutting relationships (15), and the peripheral arrangement of pegmatites and aplites (16) are very suggestive of an igneous origin for this mass. However, these same features have been denied by proponents of granitization to be valid evidence for magmatic origin in many instances. Therefore, they are offered here

only as facts that must be explained. The presence in this region of many alaskitic bodies that are restricted to crests and troughs of folds (17) and the general lack of alaskite on the limbs of such folds could be accounted for by either hypothesis; such zones of low pressure during folding likely would facilitate the movement of either granitizing agents or magma during folding.

The balance of evidence, though much of it is admittedly only permissive evidence, suggests that this body resulted from the consolidation of a magma rather than by granitization.

Emplacement. No attempt is made to explain how the magma rose into the crust from greater depths, if indeed it did. It is attempted only to explain how the alaskite came to occupy its present position. It is concluded that the emplacement of the alaskite magma was accomplished mainly by permissive intrusion¹ into potential cavities created by the stresses at the trough of a fold, during folding. Minor features also suggest that lit-par-lit injection and assimilation might have been important locally during the emplacement.

The general type of injection thought to have been mainly responsible for the emplacement of the Fish Creek alaskite may be explained as follows: It is considered possible that during folding, crests and troughs of folds became zones of weakness and general tension whereas the flanks of the folds became relatively compressed. If the materials being folded have competencies such that they will flow during the folding, folds will be produced that show thickening on their noses and thinning on their limbs, the amount of thickening depending on the mobility of the material involved, i.e., the more mobile the material, the greater the relative thickening on the noses; if, on the other hand, the materials involved have competencies such that they will fracture rather than flow under the conditions of the folding, there will be a tendency for openings to form along planes of weakness (e.g., foliation planes or bedding planes) at the crests and troughs of the folds. If igneous magma were present during such folding, it probably would find its way into the zones of weakness along the crests and troughs of folds in the more rigid rocks, forming concavo-convex, lenticular-shaped masses upon consolidation. After the initial permissive introduction of the magma, there probably would be a progressive movement into the potential openings, with further enlargement of these interspaces until the original rock would be completely dismembered and would become discrete fragments within the magma or the mush

¹ Permissive intrusion was defined by Pirsson (1914, p. 299) as intrusion in which the magma is emplaced by flowing into space opening for it, the openings being formed by some force other than one exerted by the invading magma.

resulting from the partial crystallization of the magma. The enlargement of the interspaces between fragments of the country rock might be dependent upon continued folding, simultaneous with addition of more magma, or it might depend upon spreading apart of the layers by forces exerted by a partly aggressive magma. Whichever the case, if enough magma were supplied, it would finally become the predominant member of the unit and when this occurred, the unit would act like a mobile material so long as any part of the magma retained its fluidity.

This general type of intrusion is believed to have been important in the emplacement of the Fish Creek mass because it appears to explain all the features associated with the mass, and because it appears to explain some features associated with the mass that cannot be explained reasonably by any other mode of emplacement with the possible exception of palingenesis in situ. Some of the latter features and explanations afforded them by this mode of intrusion may be listed as follows:

1. The relative thickening of the nose of the lenticular alaskite mass is greater than the relative thickening of folds involving country rocks—even those involving the highly plastic Grenville marble. If the magma became the predominant member of any unit involved in folding, during the folding, a notable thickening of the nose of that fold would be produced. This thickening would probably be even greater than that of folds involving the most mobile country rocks, because magma would be more mobile than the most mobile rock.

2. There are many inclusions in the Fish Creek mass that have observed thicknesses of less than 2 inches and observed minimum dimensions along the strike and parallel to the dip that are 5,000 and 500 times the thickness. Typically, these sheetlike inclusions have an internal foliation parallel to their borders and most of the inclusions are oriented parallel to the foliation of the granite. There is a concentration of the inclusions that are not oriented parallel to the foliation of the granite exposed along a line that nearly divides the mass symmetrically. This line has been interpreted as the trace of the axial plane of the mass because the pattern of the foliation of the xenoliths appears to outline a fold with the trace of its axial plane in this position. An igneous mass emplaced in the manner here suggested might contain peculiarly shaped inclusions and there possibly would be a distinctive relict arrangement of the inclusions, i.e., a general arrangement suggesting the relationships of the fold that involved only the country rocks. If the rock intruded were a foliate (as is indicated here), failure during folding might be manifest by a fracturing parallel to the folia-

tion as in flexure folding. Introduction of magma along these fractures might cause the engulfment of very thin, sheetlike inclusions of country rock, a kind of inclusion not met in most intrusions but found in many places in this mass. The original arrangement of the foliated inclusions would likely have been modified by the flowing of the magma, producing a tendency to orient the xenoliths parallel to the foliation of the granite. However, the xenoliths might retain a relict pattern, generally outlining the structure that the foliate had before intrusion of the magma.

3. The fabric of the alaskite gneiss of this mass differs greatly from place to place. In some places, it has undergone marked cataclasis; in others it appears to have recrystallized completely, and in still others it appears to have undergone neither cataclasis nor recrystallization.

In the field, foliation is apparent at all outcrops. Most of it appears to be an axial plane foliation, but locally there are swirls around the ends of xenoliths and other features that indicate that part of the gneissosity is primary. None of these different types seems to have any regular spatial pattern and typically they appear to grade into each other imperceptibly. It is suggested that one zone may have been undergoing postconsolidation cataclasis or recrystallization while a nearby zone may have been still in a magmatic or mush state. If one were to deduce the type of foliation that would probably be present in a mass emplaced as suggested above, these very features would be expected. The foliations present would represent many different relative periods in the consolidation of the magma, and thus owe their origin to different conditions. The foliation would be in part primary flow foliation, in part dependent upon original crystallization under the influence of directed pressure (tectonic), in part owing to forces active upon a mush and in part imposed by forces active upon a completely consolidated portion of the magma. The temperature or fluid content of the rock might explain why the consolidated portions underwent cataclasis in some places and recrystallization in others; greater heat or the presence of fluids may have facilitated recrystallization. Extremely localized controls (e.g., proximity to inclusions) may have effected the differences; thus, the diverse types of foliation would be expected to grade into each other.

There are many other features associated with the Fish Creek mass, e.g., its generally concordant nature, that can be explained equally well by other methods of emplacement, but no mode of emplacement, except syntectonic, permissive intrusion into a fold (with the possible exception of palingenesis in situ), has been found that is in complete accord with the thickening on the nose of the mass, the orientation and

peculiar shapes of inclusions in the alaskite and the fabric differences in the alaskite. Because of this accord and also because of the fact that no known features of the mass preclude this mode of emplacement, it is concluded that the Fish Creek alaskite was so emplaced.

Postemplacement history. Subsequent to the emplacement of the Fish Creek mass, the alaskite has been: (1) intruded by melanocratic dikes; (2) subjected to at least local metamorphism; (3) intruded by basaltic dikes, and (4) uncovered by erosion at least twice, i.e., before and after Potsdam sedimentation. The postemplacement history probably was further complicated, but no definite evidence for further complexities has been found.

It is apparent that at least local dynamic metamorphism took place after the emplacement of melanocratic dikes, because the dikes are now amphibolite and they are locally faulted. The basic dikes that cut the alaskite near the south margin of the mass have been described (p. 59). The present exposure of the Fish Creek mass and the fact that the alaskite is overlain unconformably by Potsdam sandstone proves that the mass has been uncovered by weathering and erosion at least twice since it was emplaced.

Theoretical considerations. As mentioned before the Fish Creek mass is one of 14 alaskitic bodies in the northwestern Adirondacks that Buddington considered to be phacoliths. He believed that the magma that formed these bodies was intruded along the crests of anticlines contemporaneously with folding and was further compressed with the strata before complete consolidation. His conclusions were based on restriction of the bodies to anticlinal folds, general conformity between the borders of the masses and the bedding of the country rocks, actual exposure of the base of one of the bodies, primary foliation indicating contemporaneity of folding and intrusion, and pronounced thickening on plunging noses and crests of several masses.

Because some texts of igneous petrology give definitions of the term phacolith that deviate from common usage (e.g., Hatch, Wells and Wells, 1949, p. 152 "... a lens-shaped intrusion of concavo-convex shape situated in the core of an anticline. The phacolith owes its shape to intrusion into preexisting folded strata, ..."), the literature was reviewed (summarized below) to find what actually is embodied in the original definition of the term and to find how the term has been applied since its introduction.

When first introduced, the term phacolith not only defined the shape and structural relationships of a certain kind of igneous body, but it also embraced a time-tectonic intrusive relationship—the type phacolith

was considered to be a generally concordant, lenticular intrusive that was emplaced contemporaneously with the folding of the enclosing strata. Because the type phacolith has a horizontal axis, some authors have been reluctant to apply the name to structurally similar bodies that do not have near-horizontal axes; others have not interpreted the original definition as being so restrictive and have applied the term to syntectonically intruded, concordant, lenticular masses regardless of their attitude.

Growth of the phacolithic concept. Intrusive bodies occurring along crests and troughs of folds in country rocks have been recorded from many parts of the world.

This type of intrusion was well described in 1897 by W. H. Weed (1897, pp. 811-812) under the title "Laccoliths in folded strata." He reported the occurrence of lenticular masses of intrusive rocks along axes of folds, vaguely locating them as "in the mountain groups of the plains of Montana, and in one of the front ranges of the Rocky Mountains." He also stated that he believed that the intrusion of these masses accompanied folding, and that their position was dependent upon the existence of less pressure at crests and troughs than along limbs of folds.

The name PHACOLITE (Greek; *Phakos*-lentil and *lithos*-stone) was given to those intrusive bodies whose "situation, habit, magnitude and form... are all determined by the circumstances of the folding itself" by Alfred Harker (1909, pp. 77-78). The type body is a dolerite mass in the Ordovician strata of Shropshire, England.

Phacolith, rather than "phacolite" has appeared in all subsequent publications except Vogt's paper on the Sulitelma district of Norway.

J. C. Martin (1916, p. 29) described a steeply plunging "half sill-like, half bosslike body of granite... intruded previous to and probably also in large part during the period of folding," in the Grenville province of northwestern New York. He did not use the term phacolith—possibly because the body has a nearly vertical axis.

The term appears to have been first used in Norwegian literature when Steinar Foslie (1920, p. 11) applied it to the syn-Caledonian Raana norite mass, which intruded Cambro-Silurian sediments.

The term HARPOLITH was introduced by Cloos (1921, pp. 44 and 84) when he described a lenticular granitic mass in Silesia having a nearly vertical plunge. This body has essentially the same structural relationships as a phacolith—"Harmonisch eingefügt in den Bau..."—so it appears to the writer that the name harpolith is superfluous. In his "Einführung in die Geologie" (1936, p. 63) Cloos in fact treats phacolith and harpolith as synonymous terms.

The syntectonic relationship of many of the lenticular masses in the Grenville province of New York and Canada was suggested by H. P. Cushing (1925, p. 55) and M. E. Wilson (1925, pp. 397-399). Some of these concordant granitic bodies in the Canadian Grenville province were actually called phacoliths by Wilson. He noted that they increase in thickness on the crests of the folds and have field features that indicate the magma underwent deformation during its consolidation.

Prompted by Foslie's report, Thorolf Vogt (1927, pp. 136-185, 249-260, 278-319, and 347-363) reclassified some of the igneous bodies in the Sulitelma district of

Norway as "phacolites." Previously, these masses were called laccoliths. He discussed in detail one granite and two gabbro bodies. He discussed also Cloos' term "harpolith," and suggested that the term "phacolite" should be extended to include all generally concordant, lens-shaped intrusive masses—"the lenses may be biconvex or concavo-convex and their inclination towards the horizontal may vary"—that have been emplaced under the influence of mountain-forming processes.

In 1929, two papers concerning phacoliths were published: T. W. Gevers and H. F. Frommurze (1929, pp. 39, 50-55) described granite phacoliths in South West Africa and as already mentioned A. F. Buddington (1929, pp. 51-107) described granitic phacoliths in the northwestern Adirondacks.

Phacoliths have been mentioned in many subsequent reports on areas within the Grenville province of New York (Buddington, 1934, 1939; Reed, 1934; Cannon, 1937).

A structural study of a plunging synclinal phacolith—the Precambrian Wolf Mountain granite body, Llano, Texas—was made by H. B. Stenzel (1936, pp. 361-367).

The "domes" of the Oliverian magma series located just northeast of Hanover, New Hampshire, have been interpreted by J. B. Hadley (1942, pp. 159-166) to be phacoliths. He believes, however, (personal communication) that these bodies are complex, in part migmatitic, and that they have controlled to a considerable extent the shapes of the folds in which they are found.

M. S. Walton (oral communication, 1949) has found granite and granite porphyry phacoliths in the Paradox Lake quadrangle of the eastern Adirondacks, New York. These comprise both synclinal and anticlinal phacoliths, and their axes range from near horizontal to near vertical.

There are many other bodies, designated as sills, laccoliths, folded batholiths or the like in the literature, that appear to fit the phacolith concept.

The writer considers that the phacolith concept involves the syntectonic (synkinematic) intrusion of magma along crests and/or troughs of folds in country rocks. The resulting igneous masses are lenticular and generally concordant, and may have any spatial attitude. Therefore, to prove that a body is a phacolith one must demonstrate that: (1) the body resulted from the solidification of a magma; (2) the magma was intruded syntectonically, and (3) the body is restricted to the crest or trough of a fold. Establishing these features eliminates the other possibilities that would be theoretically the most difficult to distinguish from phacoliths, i.e., folded sediments that have been granitized, folded sills, folded laccoliths and igneous masses that have intruded folded sediments.

Conclusions. It has been shown that the Fish Creek alaskite mass occupies the trough of a syncline and that it has a general lenticular cross section. Evidence has been presented suggesting that the alaskite owes its origin to the consolidation of a magma and that the magma probably gained its present position by syntectonic intrusion. On the basis of these and other features, the mass is considered to be a synclinal phacolith that has been somewhat deformed since its emplacement.

PALEOZOIC ROCKS

General statement. The Paleozoic rocks in the Brier Hill quadrangle were mapped in conjunction with this investigation because they constitute a large potential source for building materials which may prove to be of great value in promised future developments within this general region. A generalized lithologic map of the Paleozoic formations and noteworthy lithologic features observed during this mapping are presented here because of their possible bearing on future utilization of rocks in the region and to facilitate the discussion concerning building materials in the section on mineral resources.

Upper Cambrian (?) Potsdam sandstone and Theresa formation and the Lower Ordovician Ogdensburg dolomite occur within the mapped area. Much of the area west of Black Lake and a small portion of the surface near the east border of the quadrangle are underlain by these sedimentary rocks.

Potsdam sandstone. The Potsdam sandstone, named by Emons (1838, p. 214), lies with angular unconformity on the Precambrian metamorphic igneous rocks. It grades upwards into the overlying Theresa formation. The thickness of the Potsdam is variable: the lower strata occur only in depressions in the Precambrian surface; the upper strata are more continuous, although they, too, are locally absent. The thickness of the formation (Cushing 1916, p. 24) ranges from "0-60'" in this general region. Recent well data suggest that, locally, the formation is at least 125 feet thick.

Most of the formation is composed of white, coarse, well-sorted, quartz sandstone, though red sandstone and red and white inter-laminated sandstone are present locally. Irregular lenses of sedimentary breccia and conglomerate occur at different horizons in the sandstone and two lenses of well-developed sandstone concretions were observed in the formation. Oscillation type ripple marks and cross-bedding are present sporadically. At a few places where crossbedding occurs, adjacent layers show foreset beds dipping in opposite directions. These features suggest that the Potsdam is a strandline facies in this vicinity.

Only three observable contacts between the Potsdam sandstone and the underlying Precambrian rocks were found, though many contacts were located approximately.

1. A contact between a breccia lens and biotite granite is located at the intersection of the Oak Point road with $75^{\circ} 45'$ W. longitude. This is well marked because of the different rocks involved.

2. A contact between arkosic sandstone and the Fish Creek alaskitic gneiss is present one-half mile southwest of School 7 east of Black Lake. This contact is poorly defined and is best described as gradational, despite the differences in lithologies, and ages and modes of origin of the two rocks.

3. This contact is between the sandstone and the Oak Point quartzite inlier, southeast of Oak Point. The contact has special interest because it attests to the presence of pre-Potsdam joints in the area. The sandstone occurs as clastic dikes between joint surfaces in the Grenville quartzite. Similar but much smaller clastic dikes of Potsdam sandstone also occur in the Fish Creek alaskitic gneiss.

Two different types of contacts between Potsdam sandstone and Precambrian rocks have been reported. Chadwick (1920, pp. 17-20), Smyth (1901, pp. 98-101) and Buddington (1934, pp. 173-177) described the deeply weathered condition of the Precambrian rocks of the contact zone; Cushing (1910, p. 60), Wright (1923, p. 10) and Reed (1934, p. 30) gave descriptions of remarkably fresh and unweathered Precambrian rock beneath the contact. The Precambrian rock at the three contacts within this area is unaltered.

The upper part of the Potsdam sandstone has both calcareous and siliceous cement and grades into the Theresa formation. Thus, the division between the two formations is arbitrary. The division made in this study was at the base of the first blue-gray, calcareous siltstone.

Most of the Potsdam sandstone is white on fresh and glaciated outcrops and buff or gray on weathered outcrops. Good examples of glaciated outcrops occur along Route 37 south of Brier Hill. Examples of cliff exposures are present south of Brier Hill on the west side of Chippewa Creek Valley and southwest of Delack Point along the eastern shore of the St. Lawrence River.

Microscopic examination shows that most of this white sandstone consists of nearly pure silica, occurring as well-rounded quartz grains with an authigenic quartz cement which is in optical continuity with the nearest grains. It is thought that at least some of the authigenic quartz could have been derived from the enclosed sand grains because of the fact that complementary sutured borders are found between some adjacent grains. All of the quartz shows undulatory extinction. A few rounded tourmaline grains and zircon crystals are present in most thin sections. Locally the feldspar content ranges to an estimated 20 percent. Some of the sandstone has calcite as part of its cementing material. Grains of quartzite and of quartz with included sillimanite needles, showing a preferred orientation, are also present locally, attesting to a metamorphic terraine source area.

Locally, the sandstone is completely red or is red and white inter-laminated. Some of the outcrops within the Chippewa Creek Valley and along the valleys of Black Lake and the Fish Creek Swamp are the best examples. Under the microscope this type of sandstone is like the white variety except for the presence of a brownish-red coating on the sand grains. Thermal analyses were made of the sandstone to try to determine the identity of the pigment. Except for the endothermic reaction at about 575° C., due to the inversion of quartz, no variation was found in the heating curve. This suggests that either the pigment is hematite as previously postulated, rather than the goethite, as suspected, or that the percentage of goethite present is too low for detection by this method. The coating is definitely preauthigenic quartz, because it embays the sand grains but not the authigenic quartz. The presence of alternating lamellae of less than one millimeter thickness of coated and noncoated grains suggests that the pigment was deposited contemporaneously or penecontemporaneously with sedimentation.

Sedimentary breccia and conglomerate lenses occur at different horizons within the formation. Good examples of these lenses may be seen on the shore of the St. Lawrence River just north of Oak Point, on the east side of the Oak Point quartzite inlier and near the road at Point Comfort. The size of the fragments ranges from small pebbles to boulders. Some lenses are made up of rounded fragments—true conglomerates; others have only very angular or slightly modified joint and/or cleavage fragments—true breccias. The pieces range in sphericity and typically the well-rounded ones are more nearly spheres. Imbrication of fragments is not apparent. More than 95 percent of the fragments are quartzite, not unlike that found in the nearby Grenville (?) quartzite masses. Cobbles of vein quartz and of pegmatitic intergrowths of quartz and tourmaline have also been found. The breccias and conglomerates have sand matrices and are cemented by either siliceous or calcareous material. Though the relationships of many other lenses are not apparent, some of the lenses plainly owe their origin to filling of channels cut in the sandstone. The areal extent of these lenses is obscured by Pleistocene material. Present evidence does not appear to fit with any simple hypothesis of origin for these lenses.

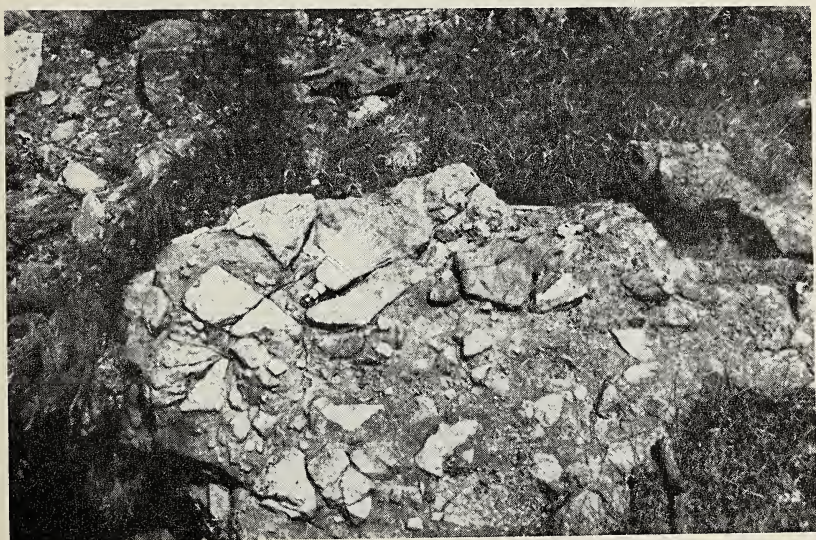
Sandstone concretions occur in the white sandstone ledge facing the St. Lawrence River at Oak Point. Similar concretions are present on Wellsley Island (along the Thousand Island Bridge Highway approximately one-half mile south of the custom house) in the Grindstone quadrangle, southwest of the Brier Hill quadrangle. Typically, the concretions are oblate spheroids with their shorter diameters perpendicular to the bedding planes; some complex forms show a tendency

PLATE 20

Potsdam conglomerate-breccia



A. Conglomerate-breccia lens within the Potsdam sandstone. Line is along conglomerate-breccia—sandstone contact. (Oak Point)



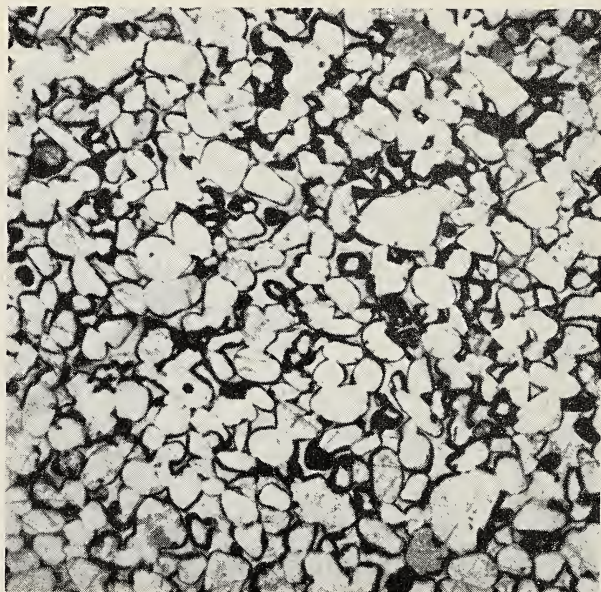
B. Potsdam conglomerate-breccia. (Oak Point)

PLATE 21

Potsdam concretions and a photomicrograph of typical Potsdam sandstone



A. Potsdam concretions (sandstone)—the compass to the right of the center indicates the scale. (Oak Point)



B. Photomicrograph of typical Potsdam sandstone. Note the coating (hematite) on the grains; note also how some adjacent grains have complementary sutured borders, apparently indicating solution on contact surfaces between grains. (x25, plane polarized light)

toward bilateral symmetry. The oblate spheroids range in size from about $\frac{1}{2} \times \frac{3}{4}$ inches to 10×13 inches. Though most concretions have smooth surfaces, those with mammillary protuberances are not uncommon. Some of the cavities formed by removal of the concretions show coatings of iron oxide.

As always, where concretions are involved, there are questions concerning the time of formation: Are the concretions pre- or postsedimentation? Are they pre- or postinduration of the host rock? The following objective data seem to be pertinent:

1. Microscopically, the concretions, the matrix between concretions and nearby concretion-free sandstone are apparently identical. They are all like the above described white sandstone.

2. The specific gravity of the concretions, the matrix and the nearby concretion-free sandstone is the same.

3. One ripple mark surface was found that is crossed by the concretions.

4. Some of the concretions have the sedimentary laminations extending right through them.

5. Faulted concretions are present; these faults are of the slump type, i.e., lamellae immediately above and below faulted lamellae are unaffected.

The above data seem to point quite definitely to the formation of these concretions penecontemporaneous with deposition. They were formed postdeposition and pre-induration.

Theresa formation. Cushing (1908, p. 161) gave the name Theresa formation to the "passage beds" between the Potsdam sandstone and the Beekmantown formation. When he introduced the name, his paragraph heading was "Theresa dolomite," but "Theresa formation" is the only term applied to the formation in the rest of the article. "Theresa dolomite" is the term accepted by the United States Geological Survey's Committee on Geologic Names. The writer uses the name "Theresa formation" because he believes the dolomite connotation is misleading in view of the variability of the formation.

Chadwick (1915, p. 289) suggested that the sandstone, 20 feet thick, at the top of the formation should be separated and given the name "Heuvelton sandstone." Cushing (1916, pp. 29-35) followed this suggestion despite his statement, "It is, however, but one out of several thick sandstone zones in the formation; there are three or four others with a thickness of from 8 to 10 feet, which may readily be mistaken for the other where outcrops are poor." The Heuvelton sandstone has not been differentiated in the present mapping because of this chance of error.

The Theresa formation, reported to be 140 feet thick by Cushing (1916, p. 24), is composed of white sandstone, gray and buff calcareous sandstone, blue-gray sandy limestone, and buff and gray sandy dolomitic limestone in alternating beds. The arbitrary division between this formation and the underlying Potsdam formation has been mentioned. The formation is separated from the overlying Ogdensburg dolomite by an erosional disconformity. This disconformity, with at least 10 inches relief on the Theresa may be seen in the creek bed about 200 feet northwest of the Church Road-Poverty Street junction in the Town of Oswegatchie. Where the disconformity is not visible, it is difficult to distinguish between the Theresa formation and the Ogdensburg dolomite because the formations are lithologically similar near the contact. Although fossils are present in both formations, no guide fossils are sufficiently abundant to be of great value.

In this study, the contact, where not observable, is inferred on the following bases:

1. The top of the Theresa formation is a plane surface.
2. The strike and dip of this surface is nearly constant.
3. The Ogdensburg formation is above this surface unless otherwise proved.

The first two assumptions appear to be rather safe extrapolations from the observable surface to the south. The third assumption may be contrary to the facts because much of the topography of the northern part of the quadrangle probably expresses thick glacial deposits rather than bedrock topography. Thus, some of the area mapped as Ogdensburg dolomite is likely underlain by the Theresa formation or even some older rock.

Outcrops of the Theresa formation are of two general kinds: scarps occur along Chippewa Creek, the west shore of Black Lake and the east shore of the St. Lawrence River, and low benches with soil-covered vertical exposures and bare upper surfaces of one of the more resistant sandstone layers are common in many places. The scarps along the St. Lawrence River present the most complete sections. Typically, Theresa outcrops are deeply weathered except for the more resistant sandstone layers. The calcareous sandstones are brown and in some places typical "rotten rock"; the sandy limestones are rusty or crumbly; some of the dolomitic layers have chamois-like weathered surfaces.

Microscopically, most of the white sandstone layers are identical with the white Potsdam sandstone. However, one type is notable because it has spherical blebs of calcareous cement peppered throughout.

The finely laminated calcareous sandstone, as seen in thin section, consists chiefly of quartz and feldspar fragments with scattered detrital tourmaline, rutile and muscovite along with an organic (shell frag-

ments) phosphatic material. The cement is authigenic quartz and calcite; the authigenic quartz is in optical continuity with the nearest quartz particles; the carbonate cement, indicated to be calcite rather than dolomite by staining tests, is in irregular blebs throughout the rock. The calcite cement may have been secondarily introduced. This rock could be regarded as a fine-grained calcareous arkose (Oriol, 1949). However, it is very unlikely that anyone would apply the name arkose to the rock in the field.

The sandy limestone consists of the same minerals (but with calcite sand) as the calcareous sandstone, described above.

The dolomitic limestone is a crystalline limestone with large crystals of dolomite. Staining indicates that the rock is in a large part dolomite. The stain pattern, showing dolomite cutting across sedimentary lamellae, suggests postdepositional dolomitization. A few scattered grains of quartz, feldspar and tourmaline are present. The fact that these dolomite layers make up less than 10 percent of the formation shows that "Theresa dolomite" is a misnomer.

Ogdensburg dolomite. The name Ogdensburg dolomite was given by Chadwick (1915, p. 289) to the formation above the erosional disconformity at the top of the Theresa formation. The Ogdensburg was correlated (op. cit.) with the upper Beekmantown of the Champlain Valley of northeastern New York.

The lower contact has been described in the previous section; the top has not been found to occur within the area. The thickness is given as 120 feet or more by Cushing (1916, p. 24).

The Ogdensburg dolomite is dolomitic at nearly all horizons. Gray-brown sandy dolomite, dolomitic sandstone, finely granular dolomite, finely crystalline dolomite, gray and brown banded and laminated dolomite, and other similar petrographic types are present. Pink, white and black coarsely crystalline calcite nodules and veinlets are present in many places, and pyrite veinlets are present locally.

Good exposures occur in quarries such as that south of Galilee in the Town of Oswegatchie, and those at the south edge of Ogdensburg and farther south along New York Route 37.

Structural geology of the Paleozoic rocks. Apparently, the Paleozoic formations have undergone only slight disturbance since induration. They are nearly flat-lying throughout the area, and very few dips exceed 10° . The regional dip, which is northeastward, may be seen best along the St. Lawrence River, where the rocks typically dip downstream.

Many high angle joints cut through the Potsdam sandstone, the Theresa formation and the Ogdensburg dolomite. They cut con-

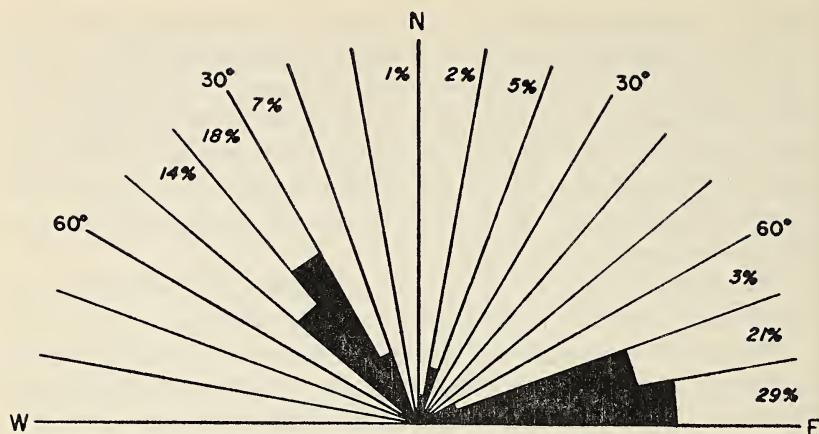


Figure 7. Strikes of joints in Paleozoic formations; the numbers express the nearest whole number percentages based on more than 500 joints; all joints are nearly vertical.

glomerate and breccia fragments in the Potsdam formation indiscriminately. Many joint surfaces in the Cambrian rocks are covered with limonite stain and/or calcium carbonate "flowstone." Those in the Ogdensburg dolomite show marked solution effects, such as rounded edges where bedding planes intersect joints. Though joints with many different strikes are present (figure 7), two sets predominate; these are N. 75° to 90° E. and N. 25° to 45° W. The distance between apparent adjacent joints ranges from less than 1 inch to nearly 6 feet, and some outcrops of more than 25 square feet show no joints.

Cushing (1916, p. 53) reported the presence of a fault at Point Comfort, which is about 3 miles southwest of Morristown on the St. Lawrence River. The presence of the fault was inferred mainly on the presence of conglomerate to the north of a certain area and its failure to occur to the south of the same area. This interpretation was based on the tenet that the conglomerate is a basal one. It is really a lens within the sandstone as stated above. No evidence of faulting could be found in this area—in fact, a Precambrian quartzite inlier crops out in the area where "the fault zone shows no outcrops but is occupied by a drift-filled depression. . . ."

Minor displacements—probably preinduration slump phenomena—are present in the Potsdam sandstone near the south edge of the Brier Hill quadrangle, just northeast of Popes Mills. These relationships are well outlined by red and white laminations in the sandstone. The displacements are thought to owe their origin to slump rather than tectonic movements because they are restricted to a few lamellae within the formation and there is no apparent distortion of adjacent lamellae above or below.

Fossils from the Paleozoic rocks. The writer did not make extensive collections of fossils from the Paleozoic rocks. The only fossils collected and identified were extremely common forms: fucoid-like markings present on many bedding surfaces in the Theresa formation; inarticulate phosphatic brachiopods belonging to the genus *Lin-gulepis* and the gastropod, *Sinuopea*, found in the Theresa formation; a simple gastropod of the genus *Ophileta*, found in the Ogdensburg dolomite. Fossil lists made from collections from this general region are given by Cushing (1916, p. 28).

MINERAL RESOURCES

General statement. Graphite, magnetite and silica sources have been investigated. They cannot be considered to be of commercial interest under present economic conditions. Various building materials available within the area may prove to be of great value in future development contemplated for this general region.

Graphite. Disseminated flakes of graphite occur within many of the Grenville rocks. Just south of the Brier Hill quadrangle, near the Town of Popes Mills, a corrugated quartz schist was worked for crystalline graphite as recently as 1944. No surface exposures within the Brier Hill area appear to contain as high a percentage of graphite as do the rocks at the Popes Mills locality.

Magnetite. Four prospect pits were opened during the late 1870's in what appear to be magnetite-bearing xenoliths or amphibolitized melanocratic dikes in the Fish Creek alaskite gneiss. The actual geological relationships of the deposits are obscured by dumps and water. Although it is reported that flooding was responsible for closing the pits, it seems more likely that the low quality and/or small quantity of the magnetite-bearing material were the main considerations. Further mapping of the deposit would entail pumping, and removal of the dump material. However, drilling and/or geophysical exploration could be carried on under the present conditions.

Silica. In the Canadian area across the St. Lawrence River from the Brier Hill area, Grenville quartzite and Potsdam sandstone have been examined as possible sources of silica (Cole, 1923, pp. 10-11 and 45-46; Keith, 1946; Hewitt, 1952, pp. 11-15). No Grenville quartzite beds of large size were found that are sufficiently free from impurities to be of commercial value at prevailing prices. However, Potsdam sandstone, locally nearly pure silica, has been quarried and processed for silica at two quarries near Kingston, Ontario, for about a decade. The sandstone is run through a rod mill and a hydraulic

classifier and the product (sand) is shipped for use in the manufacture of silicon carbide and for use as foundry sand.

Potsdam sandstone of the Brier Hill area is for the most part as pure as or more pure silica than that being quarried and processed in the Kingston area. It is located near routes of inexpensive transportation. The sandstone must be considered to be a large potential source of nearly pure silica.

Building material. Workability, strength, durability and economy govern use of different construction materials. Within this and adjacent areas, rocks which have been used as dimension stones and as aggregate include quartzite, quartz syenite gneiss, alaskite gneiss, melanocratic gneiss, marble, sandstone of the Potsdam and Theresa formations, Ogdensburg dolomite and unconsolidated sand and gravel. Today they are used almost exclusively as aggregates for road building and road maintenance. Aggregates must be selected very carefully because they comprise the large part of both cement and bitumen base mixes. They must fulfill many physical and chemical requirements such as those related to strength (abrasion, resistance, hardness, toughness), cementing value (particle shape, particle size gradation, surface texture), mineralogical composition, structure, porosity, density, light reflection and transmission properties, and water absorption. For nearly all important uses, construction engineers set up definite specifications for aggregates and they have readily accessible aggregate materials tested to determine their fitness. Rocks within the area that might serve as sources for aggregate have not been submitted to such physical and chemical tests by the writer. However, he has noted previous performance of aggregates and has made petrographic studies of these rocks.

The quartzite, quartz syenite gneiss, alaskite gneiss and melanocratic gneiss have locally undergone marked cataclasis and, although they make passable rubble, are not satisfactory aggregates for many uses. However, because of their proximity to road projects they probably will continue to be used intermittently. Within the general region, marble of the Grenville series has been quarried and used for dimension stone and burned for lime. Because of impure quality and patchy distribution, the marble within the Brier Hill quadrangle has not been exploited in the past nor is likely to be in the future.

Potsdam sandstone has been quarried in small amounts at numerous places along the scarps adjacent to the St. Lawrence River and Black Lake for building and flagging material. Within the area, many complete buildings and the foundations of nearly all buildings are made of this rock. Large flagstones ranging in color from dark red to nearly pure white can be quarried and all of them are attractive building

stones. One quarry at Oak Point has been worked intermittently to the present. The Potsdam sandstone also is used extensively for road metal, but some of it crumbles easily and is not well adapted for this use.

There are many quarries in the Ogdensburg dolomite. The large quarry at the south edge of Ogdensburg, the quarries along New York Route 37 south of Ogdensburg and the quarry near Galilee have yielded large amounts of road metal. The rock is well suited for both building material and road metal.

Three large sand and gravel pits, the Stout pit and the Rogers property on Sand Street, near Brier Hill, and the pit at Edwardsville, are still being worked. There are also numerous small pits that are worked intermittently. Some of the sand and gravel is of poor quality because of high clay and/or high organic content, but some of it is good clean sand and gravel. At the three large pits, all of which are in outwash material, sand and gravel for concrete is available by selective working, without screening, and the remaining material is used for road metal. At the smaller pits, sand and gravel is generally of good quality but of small quantity. These small pits are located in sandy portions of the ground moraine. The most used aggregates, dolomite and sand and gravel, are described more fully below from the viewpoint of aggregate use.

Fresh unweathered samples of Ogdensburg dolomite have been collected from outcrops, quarry walls and quarry crush-fractions. The Ogdensburg formation is made up chiefly of alternating beds of thin-bedded, brown-gray, fine-grained dolomite and thick-bedded, gray, granular dolomite with sporadic calcareous and sandy calcareous beds near its base. Locally, the formation is veined by carbonates and pyrite.

The dolomite is easily procured. In most places the cover is not of great thickness, the rock is jointed throughout, it is present near main highways and it is near ample water supplies that can be used for washing.

Most Ogdensburg formation aggregate is now being used for bitumen mixes, though it is considered good aggregate for both macadam and concrete. The presence of deleterious pyrite and the presence within the smaller crush fractions of many lath-shaped particles may be considered undesirable. However, pyrite is present only locally, and even in such places in small amounts; pyrite-bearing dolomite can be avoided altogether if care is taken in locating quarries. No ill effects attributable to lath-shaped particles in the aggregate have become apparent to date. Aggregates from the Ogdensburg dolomite are generally sharp, angular and hard. All engineers interrogated report that the aggregate has very good wearing qualities. They attribute difficul-

ties such as those apparent during the freezing and thawing seasons to the time of placing of mixes, to the protection afforded mixes after placing (during inclement weather), and to poor selection of subgrade materials in areas having drainage problems rather than to inherent aggregate weaknesses.

Sand and gravel samples were taken from three currently worked pits in this area—the Stout pit and the Rogers pit south of Brier Hill and the St. Lawrence County pit at Edwardsville. Vertical and horizontal channeling with wide coverage and with care to include all types was the sampling method employed. The samples were sieved by John Graham in the laboratories of the State Science Service and the sieve fractions have been studied microscopically by the writer.

Sand and gravel from these pits ranges greatly in size and degree of sorting both vertically and horizontally. However, similar size fractions from the different pits are similar in composition and particle shapes. The results of the sieve analyses of the sand and gravel samples are presented on table 7. In the plus 60 mesh⁸ sizes, rock fragments, such as quartzite, various gneisses, granite, sandstone, limestone and claystone, predominate over mineral fragments. In the minus 60 mesh size fractions, mineral fragments, such as quartz, labradorite and common "heavy minerals," predominate. With the exception of some of the sandstone, a few of the gneisses and the claystone, all of which crumble easily, most of the rock fragments appear to be sound. All of the mineral fragments are fresh and sound in most samples. A little mica is present in some of the fine (—120 mesh) fractions; clay minerals are present in minor amounts in some samples (—120 mesh). All fractions are made up typically of subrounded to subangular particles. Although there are some angular fragments in the fine (—120 mesh) fractions, even these fractions have notable amounts of subrounded particles. Organic content of the sand and gravel ranges from high to very low; it was low in most samples studied.

The sand and gravel is easily procured, completely unconsolidated. Soil cover is in general lacking and present pits and main reserve supplies are located near roads. Commonly, limited tonnages of desired specifications can be procured by selective working.

None of the areas underlain by sand and gravel has been drilled or in any way tested with the objective of outlining the vertical extents of the deposits. Such investigations are necessary to make accurate estimates of the reserves because the deposits are on irregular floors. The deposits south of Brier Hill (especially the Stout pit) have large

⁸ Mesh = A. S. T. M. $\sqrt{2}$ scale.

lateral extents; the Edwardsville pit has a small lateral extent. Other pits shown on the map are small.

Sand and gravel from this area is used for subbase and in some cases for aggregate on county road projects. It is used for cement aggregate by many private construction companies. With few exceptions, it has a good performance record. Some engineers, however, do not pass it because of its local high clay and high organic content.

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GLOSSARY

The definitions as given here are not to be considered in any way complete or all-embracing. They are given in the simplest possible form that indicates how each term is used in this report.

Minerals and terms defined within the text proper are not defined here. Most rock definitions do not include mention of varietal mineral constituents.

ALASKITE—a granite composed almost wholly of light-colored minerals.

AMPHIBOLITE—a dark-colored, gneissic or schistose rock composed essentially of an amphibole and a plagioclase feldspar (commonly andesine) in about equal proportions.

ANORTHOSITE—typically a coarse-grained igneous rock composed almost wholly of calcic plagioclase feldspar (generally labradorite or more calcic).

APHANITE—a rock in which more than 50 percent of the grains are too small to be distinguished by the unaided eye.

APLITE—a fine-grained igneous rock with a saccharoidal (sugary) texture. In this report, the unmodified term connotes rocks of granitic composition.

AUGEN—(German, *eye*) a lens-shaped mass composed essentially of a single mineral grain; common in foliated rocks.

AUTHIGENIC—a term applied to those constituents of a rock that came into existence with, or within, the rock of which they constitute a part, e.g., certain cements of sedimentary rocks.

BASALT—a dark-colored, aphanitic igneous rock composed of a calcic plagioclase feldspar (labradorite or more calcic) and $\frac{3}{8}$ to $\frac{5}{8}$ ferromagnesian mineral(s) (typically augite). Glass makes up a notable percentage of some basalts.

BRECCIA—a rock composed chiefly of coarse angular fragments of rocks or minerals.

CATACLASTIC—a term applied to a fabric of dynamically deformed rocks characterized by crushed, fragmented, bent, faulted and strained constituents.

CRYSTALLOBLASTIC—a term applied to a metamorphic rock fabric formed by recrystallization. Commonly, each mineral occurs as inclusions in each other mineral.

DEUTERIC—a term applied to the changes produced in an igneous rock during the late stages of consolidation of the magma that are in direct continuation of the consolidation process.

DIABASE—an igneous rock of gabbroic composition with a texture characterized by an excess of feldspar laths with interstitial augite and/or glass.

DIORITE—a phaneritic igneous rock composed of sodic plagioclase feldspar (typically oligoclase or andesine), $\frac{1}{4}$ to $\frac{1}{2}$ ferromagnesian mineral(s) (typically hornblende), and negligible quartz.

ENDOMORPHIC—a term referred to contact metamorphism within an intrusive.

EUHEDRAL—a term referred to grains completely bounded by well-developed crystal surfaces.

EXOMORPHIC—a term applied to contact metamorphism of country rock invaded by magma.

FELDSPATHIZATION—introduction of feldspar or alteration of minerals to feldspar.

FERROMAGNESIAN—an adjective applied to dark-colored, iron- and magnesium-rich minerals such as biotite, amphiboles, and pyroxenes. The term is also applied to rocks composed chiefly of these minerals.

FLASER—a textural term referring to small lenticles made up of granulated mineral fragments.

FOLIATE—a metamorphic rock with approximate parallelism of constituents, e.g., gneisses and schists.

GABBRO—a phaneritic igneous rock that contains calcic plagioclase (labradorite or more calcic) and $\frac{3}{8}$ to $\frac{5}{8}$ dark-colored minerals (typically augite).

GRANITE—a phaneritic igneous rock that contains quartz and potassium feldspar with or without a sodic plagioclase feldspar (albite or oligoclase) which, if present, is subordinate to the potassium feldspar.

GRANOBLASTIC—a term applied to a fabric characterized by a mosaic-like arrangement of constituents.

GRANODIORITE—a phaneritic igneous rock composed of plagioclase feldspar (typically oligoclase or andesine), $\frac{1}{4}$ to $\frac{1}{2}$ ferromagnesian mineral(s) plus notable quartz and potassium feldspar (subordinate to plagioclase).

HOLOCRYSTALLINE—an adjective referred to rocks composed wholly of crystalline material.

HOLOLEUCOCRATIC—a term applied to rocks composed of more than 95 percent light-colored minerals.

INTERSERTAL—a rock fabric characterized by the presence of plagioclase laths in a rude triangular arrangement with glass or mineral matter in the interstices.

- INTRUSIVE—any igneous rock mass that was formed by solidification of magma below the surface of the earth.
- ISOCLINAL—an adjective applied to folds whose two limbs are essentially parallel.
- LEPTITIC—a term used chiefly by Fennoscandian geologist, to refer to fine-grained, granular, metamorphic rocks composed mainly of quartz and feldspar(s).
- LEUCOCRATIC—an adjective used to refer to rocks characterized by a dominance (65 to 95 percent) of light-colored minerals.
- LIT-PAR-LIT—an adjective applied to an intrusive process in which magma is injected between foliation planes of a metamorphic rock. The resulting rock has alternate layers of country rock and injected material.
- MAFIC—a term applied to dark-colored, iron- and magnesium-rich minerals such as biotite, amphiboles and pyroxenes. The term also is applied to rocks composed chiefly of these minerals.
- MELANOCRATIC—a term referred to rocks characterized by a dominance (65 to 96 percent) of dark-colored minerals.
- MESOSTASIS—interstitial material, e.g., glass in rocks having an intersertal fabric.
- METAGABBRO—a metamorphosed gabbro.
- METASOMATIC—a term applied to rocks and/or minerals that have been substantially changed in composition by chemical replacement.
- MIGMATITE—a composite layered rock made up of igneous rock and metamorphic rock, e.g., rock resulting from lit-par-lit injection.
- MONZONITE—a phaneritic igneous rock composed of roughly equal amounts of plagioclase feldspar and potassium feldspar.
- MORTAR—a term applied to a metamorphic fabric in which small granulated fragments occupy interstices between larger grains.
- MYLONITE—a rock produced by extreme granulation and shearing associated with dynamic metamorphism.
- NORITE—a gabbroic phanerite characterized by a notable percentage of an orthorhombic pyroxene (commonly hypersthene).
- OPHICALCITE—a calcite marble with abundant serpentine.
- OROGENIC—refers to large scale crustal deformation.
- PALINGENESIS—formation of a magma *in situ* by fusion of pre-existing rocks.
- PANALLOTRIOMORPHIC—a term applied to a fabric in which no minerals have any crystal boundaries.

- PARAGENESIS**—a term used to connote sequence of formation of an assemblage of minerals.
- PEGMATITE**—a very coarse-grained igneous rock composed chiefly of interlocking grains of quartz, potassium feldspar, with or without sodic plagioclase feldspar.
- PHANERITE**—a term applied to igneous rocks in which all grains of essential minerals can be distinguished individually by the naked eye.
- PHENOCRYST**—an individual crystalline grain embedded in a groundmass of smaller mineral grains and/or glass.
- POIKILITIC**—a term applied to a fabric in which small granular grains are scattered irregularly within larger grains of another mineral.
- PORPHYROBLAST**—a metamorphic rock pseudo-phenocryst formed by growth.
- PORPHYROCLAST**—a metamorphic rock pseudo-phenocryst that is a large remnant of differential crushing.
- PROTOCLASTIC**—refers to a fabric produced by granulation of early formed minerals by differential flowage of the remaining magma.
- S-PLANES**—parallel or subparallel planes of mechanical discontinuity, e.g., stratification or shear planes.
- SCHLIEREN**—irregular (because of color, grain size etc.) streaks having blended boundaries with their igneous host rock.
- SUBOPHITIC**—a term applied to an intersertal fabric characterized by a dominance of plagioclase laths.
- SYNGENETIC**—formed contemporaneously with the enclosing rock.
- SYNKINEMATIC**—an adjective applied to processes occurring during orogenic activity.
- SYNTECTONIC**—an adjective applied to processes occurring during orogenic activity.
- SYENITE**—a phanerite composed chiefly of potassium feldspar (more than 90 percent). Quartz syenite is used in this report to refer to a rock composed chiefly of potassium feldspar with 10 to 15 percent quartz.
- TECTONIC**—an adjective referred to orogenic processes.
- XENOCRYST**—a term applied to crystals foreign to the igneous rocks in which they occur.
- XENOLITH**—a term applied to rock fragments foreign to the igneous rocks that enclose them.





THE CRAYFISHES

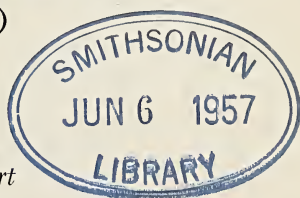
of

NEW YORK STATE

(Decapoda, Astacidae)

By

DENTON W. CROCKER
Temporary Museum Expert



NEW YORK STATE MUSEUM AND SCIENCE SERVICE

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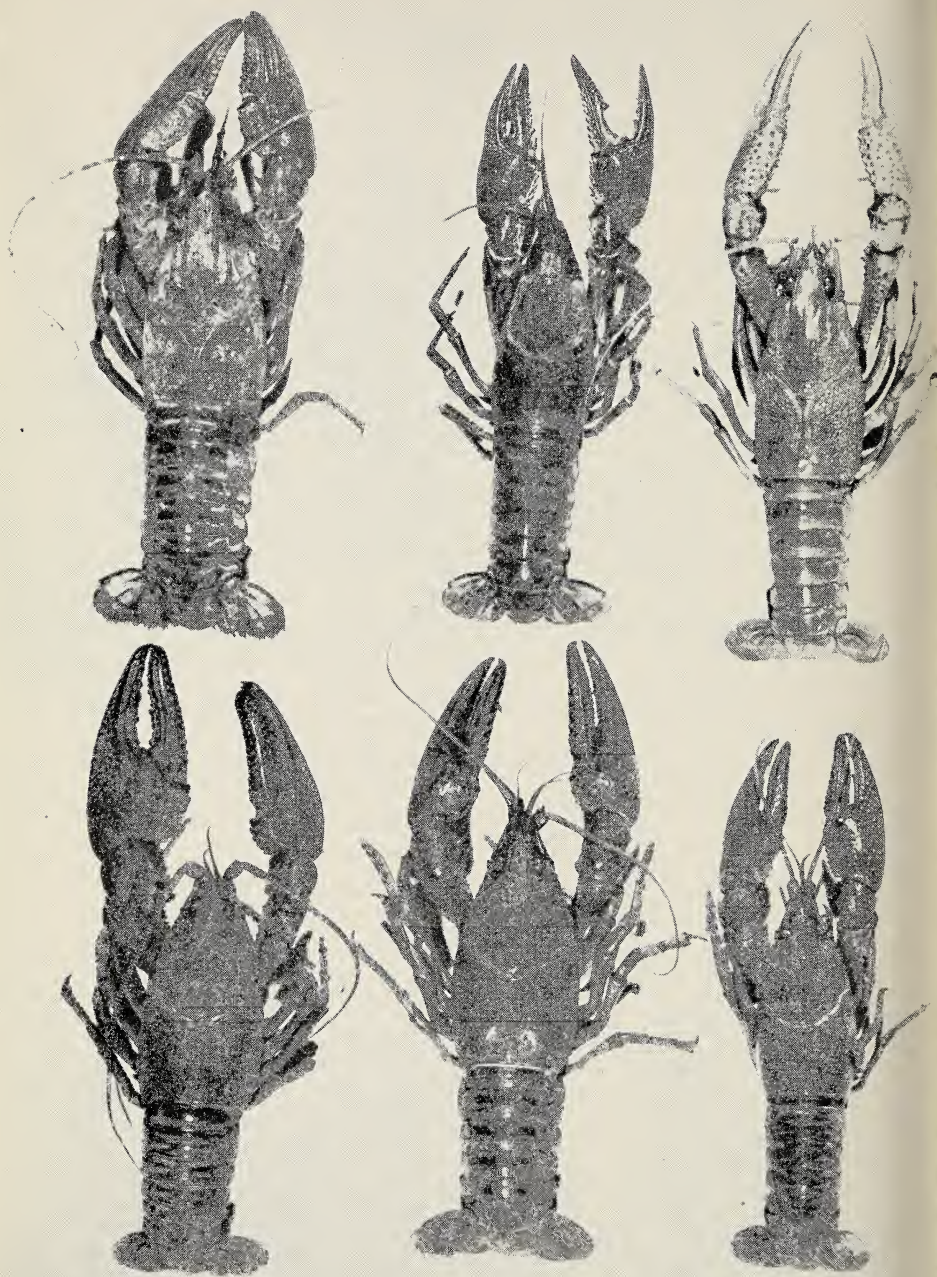
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FRONTISPIECE. Dorsal views of form I males of six of the eight known species of New York crayfishes. Upper row from left to right: *Orconectes limosus* (Rafinesque), *Orconectes immunis* (Hagen), and *Procambarus b. blandingi* (Harlan). Lower row: *Cambarus robustus* Girard, *Orconectes virilis* (Hagen), and *Orconectes p. propinquus* (Girard). Collection data for all of these specimens and drawings of their copulatory stylets (except for *O. limosus*) are on plates 2, 3 and 4 and their legends.

INTRODUCTION

Brief Historical Review

The crayfishes (or crawfishes) have long been an object of study by zoologists. Their abundance in many localities and large size (the largest of North American fresh water crustacea) make them excellent animals for zoological study. In fact, Thomas Huxley (1880) wrote a successful textbook of zoology based on this single animal group.

In 1798, Fabricius published the first description of an American crayfish, now known as *Cambarus b. bartoni*. The early published descriptions of our American species by Say (1817), Rafinesque (1817), Girard (1852) and others, were often sketchy and without figures, a characteristic of the times. The first comprehensive systematic work was a *Monograph of the North American Astacidae* (Hagen, 1870). This work was amplified and revised in the several major contributions of Faxon (1885*a*, *b* and *c*, 1890, 1898 and 1914). The taxonomy of crayfishes has undergone many changes culminating, for the present, in the generic revision of Hobbs (1942*a*), who gives a review of taxonomic changes to 1942. Besides these works of larger geographic scope, a number of State surveys have been made.

At present, H. H. Hobbs, Jr. of the University of Virginia is contributing most to crayfish literature and his excellent papers must be included among the basic materials for students of the group.

Studies of life history and ecology are many fewer than those which are primarily taxonomic. Outstanding among the former are the studies of Andrews on breeding behavior (1895, 1904, 1906*a*, and 1910*a*) and on development under laboratory conditions (1907), and the field study by VanDeventer (1937) of the biology of *Cambarus propinquus* (= *Orconectes propinquus*) in Illinois. Ortmann's report of Pennsylvania crayfishes (1906) contains valuable life history information, especially concerning *Orconectes obscurus*. More recent work has been done by Penn (1943), Bovbjerg (1952) and Smith, E. W. (1953).

Although the eight species of crayfishes which occur in New York range beyond the State and have been studied in greater or lesser degree in out-of-State areas, very few studies have been made of these crayfishes within New York State.

Tack (1941) worked out the life history of *Orconectes immunis* at Ithaca. Creaser (1934) reported on the higher Crustacea of the Raquette River system, and Nevin and Townes (1935) include crayfishes in their survey of fish food organisms of the Mohawk-Hudson.

Paulmier (1905) surveyed the higher Crustacea (including marine forms) of New York City and Dekay (1843) gives an account of historical interest of the Crustacea of the State. All other reports of the crayfishes of the State are locality records included in works of larger taxonomic or geographic scope.

Aims of Study

The zoological value of a study of the crayfishes of the State is obvious when the former lack of knowledge is realized. Several adjacent or nearby States to the south, southwest and west have been surveyed: Pennsylvania (Ortmann, 1906); New Jersey (Fowler, 1912); West Virginia (Newcomb, 1929); Ohio (Turner, 1926). These indicate that for several species or subspecies, the present study closes one of the few remaining gaps in our knowledge of their eastern and northern geographic limits.

The present study has the following aims:

1. To determine the number of species or subspecies which occur in New York State
2. To delimit the geographic ranges of the taxonomic forms occurring in New York State
3. To determine the morphological variation of the New York species, both within New York and also compared with these same forms found in other areas
4. To determine, where possible, genetic affinities and pathways of dispersal
5. To add to the often fragmentary knowledge of life histories

Materials and Methods

A major portion of this study was done as a doctoral dissertation at Cornell University (Crocker 1952). However, a considerable quantity of new data has been incorporated and the drawings have been redone.

Most of the crayfishes examined are tabulated in tables 16, 17 and 18 (pages 86-88). In addition, material has been studied at the United States National Museum (USNM) and at the Museum of Comparative Zoology (MCZ) at Harvard.

Crayfishes collected by the several Biological Surveys of the New York State Conservation Department (stream surveys) are deposited in the New York State Museum (NYSM). In 1952 I was employed by the Museum to reorganize these stream survey crayfishes and to make new collections. My report on the present organization of these specimens is an appendix to the quarterly report for October 1, 1952, of the State Zoologist to the Director of the New York State Museum, and is on file at the Museum.

To summarize the report briefly, all this material is now readily available for study. A card file in triplicate, filed by stream survey collection number, by species and by drainage system is available at the Museum as a further aid to the study of these specimens. The new collections which I made in August 1952 are NYSM catalog numbers 6977-7022 inclusive. The stream survey crayfishes are cataloged under the one New York State Museum number 6975. These are referred to in the present paper in the following form:

NYSM (year of survey): stream survey collection number.

The localities plotted on maps (figures 3-7) are all from my personal collections and the collections of the NYSM, with the single exception of the record for *Orconectes virilis* in the Raquette River which is taken from Creaser (1934: 158). The watersheds of New York and their dates of survey are illustrated in figure 2 (page 70).

The drawings of copulatory stylets and seminal receptacles (plates 1-5) were made with a camera lucida. On plate 1, figures 1-4 were drawn with a camera lucida and figures 5 and 6 were obtained by tracing on cellophane, using magnification by the method of Staniland (1953). Pubescence has been omitted from all figures. Receptacles are drawn oriented with the posterior border toward the bottom of the plate.

Collecting has been accomplished largely by seining or by turning stones and collecting by hand. Seining works best in turbid, deep or swift water. Crayfish may also be coaxed readily into a dark colored dip net by prodding with a dark stick.

In sorting specimens to permit tabulation of life history data not all specimens were measured. Therefore, for many specimens, those form II males and females, which were judged by eye to be within 1 mm. of the lower limit of size at sexual maturity (table 2), are reported as male (II?) or female (imm.?). Form II males and females measured and found to be within a few tenths of a millimeter of this value, are similarly reported.

Where "New York" is written, the State and not the city is intended. New York City will always be identified as such.

Acknowledgments

This study would not have been possible without help from many sources. Financial aid during most of my period of graduate study was provided by the people of the United States through the Federal Government under Public Law 16.

Professor Horton H. Hobbs, Jr. of the University of Virginia has been unstintingly generous of his time and materials and has given continued assistance throughout the course of the study.

The loan of Stream Survey crayfishes was obtained from the New York State Museum through the assistance of Dr. Ralph S. Palmer, State Zoologist, who has helped also in many other ways.

The Department of Conservation of Cornell University supplied maps on which the distribution data are plotted, and Professor E. C. Raney of that department has been generous with advice and criticism.

Thanks are due Dr. Waldo L. Schmitt and Dr. Fenner A. Chase, Jr. for many courtesies rendered during my visit to the United States National Museum and for the loan of specimens. Dr. Elisabeth Deichmann of the Museum of Comparative Zoology at Harvard University has very kindly loaned specimens at several different times and has put the museum collections at my disposal during my visits there.

Professor Alfred S. Romer, director of the Museum of Comparative Zoology, for several summers has generously granted me the use of table space in the Museum library, and the library staff has shown considerable patience with my many requests.

Several faculty members and numerous former students at Cornell University have contributed to my crayfish collections. To Royal D. Suttkus (now of the Department of Zoology, Tulane University) go my particular thanks for contributing perhaps as many as 5 percent of my specimens.

I am grateful to Dr. J. Seelye Bixler, president of Colby College, for two grants of money in support of my research. The Science Division of Colby College has given me a small sum of money for the purchase of publications.

I particularly wish to thank Jean-Marie J. Crocker, not only for wifely encouragement and moral support, but also for contributing materially toward the completion of this study with clerical help and assistance in the field.

The cover photograph was taken by Wendell A. Ray.

THE GEOGRAPHIC DISTRIBUTION AND SYSTEMATICS OF CRAYFISHES

Discussion

The relationship of the tribe Astacidea, to which the crayfishes belong, to other groups of the crustacean order Decapoda may be visualized by reference to figure 1. The tribe Astacidea may be separated into four families: the Nephropsidae, including the Norwegian, the European and the American lobsters; the Astacidae, which contains the European, North American and Asian crayfishes; and the Parastacidae and Austroastacidae, which contain the crayfishes of the southern hemisphere. The Nephropsidae are separable from the other three families of the tribe by the condition of the last thoracic segment, which in the Nephropsidae is fused to the carapace. The Parastacidae and Austroastacidae are most readily separated from the Astacidae by the lack in the former two families of sexual appendages (copulatory stylets) in the male.

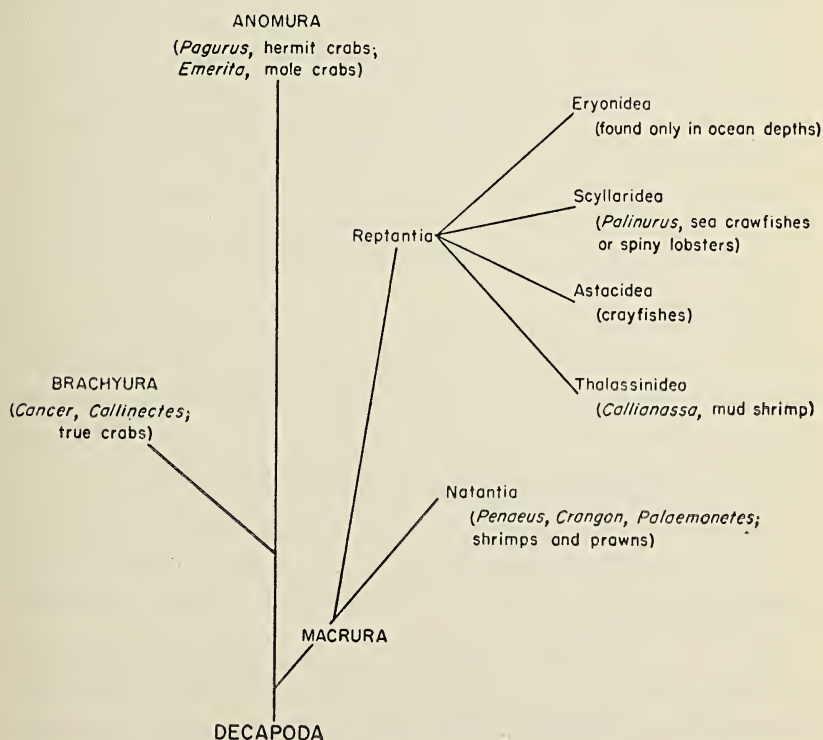


FIGURE 1. The place of crayfishes in the classification of decapod Crustacea (based on correspondence with L. B. Holthuis)

The three families of crayfishes are residents almost exclusively of fresh water (rarely brackish water), and their distributions present a striking picture. For maps of these distributions see Huxley (1880: 309), Calman (1911: 175) and Ortmann (1902: 275). Ortmann's paper contains an analysis of geologic changes which have resulted in the present distributions. These papers were written before the separation of Austroastacidae from Parastacidae by Clark (1936).

In general, the Astacidae are restricted to the Northern Hemisphere, and the Parastacidae and Austroastacidae are restricted to the Southern Hemisphere, with a tropical belt left free of any fresh water Astacidea. This tropical belt covers the area between 10 degrees north latitude and, except for the Parastacidae on New Guinea, 10 degrees south latitude. Of this distribution, Smith and Weldon (1923: 214) state the following:

It seems reasonable to suppose that the two families of Crayfishes characteristic respectively of the Northern and Southern Hemispheres have been independently derived from marine ancestors, which have subsequently become extinct. Their complete absence in the tropics is striking, and Huxley drew attention to the fact that it is exactly in those regions where the Crayfishes are absent that the other large fresh water Malacostraca are particularly well developed, and *vice versa*. Thus the large freshwater Prawns are typically circumtropical in distribution, while the South African rivers abound with Rivercrabs, which, in general, are found wherever Crayfishes do not occur.

The family Astacidae is made up of two subfamilies. The subfamily Astacinae inhabits North America west of the Rocky Mountains, and Europe and Asia. The subfamily Cambarinae is composed of the crayfishes native to North America east of the Rocky Mountains, but a number of introductions elsewhere have occurred (Penn 1954). The Cambarinae lack gills on the last thoracic somite and are separable from the Astacinae on the basis of this character. New York State crayfishes, then, are members of the crustacean order Decapoda, suborder Reptantia, tribe Astacidea, family Astacidae, subfamily Cambarinae.

The revision of Hobbs (1942a) divides the subfamily Cambarinae into the following six genera: *Procambarus*, *Paracambarus*, *Troglocambarus*, *Cambarellus*, *Orconectes* and *Cambarus*, of which *Paracambarus* and *Troglocambarus* are monotypic. At the time of Hobbs' revision (1942a) the subfamily Cambarinae consisted of 96 species,

15 of these containing a total of 47 subspecies; a total of 128 described taxonomic forms. At present there are probably about 200 described species and subspecies. The systematic positions within the subfamily Cambarinae of the eight New York crayfishes is shown in the following list.

Systematic List of New York Crayfishes

Family Astacidae

Subfamily Cambarinae

Procambarus Ortmann (1905b: 437)

Type: *Cambarus digueti* Bouvier, 1897, subsequent designation by Hobbs (1942a: 341)

Blandingi Section (Ortmann 1905a: 98)

Blandingi Group (Ortmann 1905a: 102)

Blandingi Subgroup (Hobbs 1942b: 93-94)

Procambarus blandingi blandingi (Harlan), 1830

Orconectes Cope (1872: 419)

Type: *Orconectes inermis* Cope, 1872, by monotypy.

Limosus Section (Ortmann 1905a: 108)

Orconectes limosus (Rafinesque), 1817

Propinquus Section (Ortmann 1905a: 108)

Propinquus Group (Ortmann 1905a: 109)

Orconectes propinquus propinquus (Girard), 1852

Orconectes obscurus (Hagen), 1870

Virilis Section (Ortmann 1905a: 109-110)

Virilis Group (Ortmann 1905a: 110)

Orconectes virilis (Hagen), 1870

Orconectes immunis (Hagen), 1870

Cambarus Erichson (1846: 88)

Type: *Astacus bartoni* Fabricius, 1798, subsequent designation by Faxon (1898: 644)

Bartoni Section (Ortmann 1905a: 119)

Cambarus bartoni bartoni (Fabricius), 1798

Cambarus robustus Girard, 1852

Systematic Characters in the Cambarinae

The copulatory stylets. By far the best indicators of relationships in this subfamily are the copulatory stylets and the disposition of copulatory hooks which occur on the ischia of the male pereopods. These are utilized in the diagnoses of genera (Hobbs 1942a) and even of groupings within genera (Ortmann 1905a).

The differences in the morphology of the stylets among different species have been homologized through the careful studies of Andrews (1910b) and Hobbs (1942c and 1945), which are in agreement in principle, although using different nomenclature. Further

studies of stylet anatomy and development have been made by Hart (1952, 1953 and 1956).

Among New York crayfishes there are two major types of copulatory stylet. In discussing these, the terms of orientation used refer to the stylet with its shaft aligned dorso-ventrally, its distal end (excluding flexures of the terminal elements) directed ventrad. Only the form I stylet is considered here (see below for a discussion of the two forms of the male).

One type has four terminal elements and of New York State crayfishes occurs only in *P. b. blandingi*. Plate 4, figure 5 is a lateral view of the right stylet of this species. In the figure, the distal end is toward the top of the plate. The names of the terminal elements, listed in sequence caudad (toward the right of the plate) are: cephalic process, central projection, caudal process and mesial process. The mesial process is so named because it originates proximally on the mesial surface of the stylet. The central projection is composed of two fused parts, the centro-cephalic process and, more caudad, the centro-caudal process. It is always the central projection which contains the duct through which the sexual elements pass.

The other major type of stylet has only two terminal elements, the central projection and the mesial process. The type has two distinct subtypes. In one (plate 2, figure 1) the terminal elements are both short and heavy and are bent caudad at about a 90-degree angle to the main shaft. The central projection is the one at the top of the figure (the more distal element). This subtype is the chief diagnostic character for the genus *Cambarus* (Hobbs 1942a: 354) and of New York crayfishes occurs in *C. b. bartoni* and *C. robustus*.

The remaining five New York species possess stylets which terminate in two straight (plate 3, figures 1 and 5) or gently curved (plate 4, figures 1 and 3), short (plate 3, figure 5) or long (plate 4, figure 1) elements. Such a shaped stylet is the chief diagnostic character for the genus *Orconectes* (Hobbs 1942a: 350). All of the figured stylets of this last subtype are drawn with the central projection toward the left of the plate and with the mesial process on the right.

The two forms of the male. One of the many complexities confronting the first American crayfish students was the two forms of the male, first noticed according to Hagen (1870: 22) by Louis Agassiz, who did not, however, publish this information. As late as 1870 it was supposed that an individual existed throughout its life either as one form or the other. In 1875 Faxon received a shipment of live crayfishes from Kentucky. One of the males moulted in the laboratory and upon comparing moult with moulted animal he found one to be

of one form and the remaining one of the other. His further observations and published account (Faxon 1884) settled the issue. It is now understood that adult males incapable of reproduction (known technically as form II) are morphologically different from males which are so capable (form I). It is also known that in a given individual the two forms alternate, the time of year and frequency of alternation varying with species. This phenomenon occurs only in the subfamily Cambarinae and in *Cambaroides* of the subfamily Astacinae (Hart 1953).

The major external morphological differences in the form I males are heavier, more corneous and slightly larger copulatory stylets (first pleopods) and larger hooks on those pereopods which bear them.

Other useful taxonomic characters. The use of form I stylets in keys has the disadvantage of restricting identifications to form I males. Therefore, it is desirable that other morphological features be utilized for separating species. Such features, commonly used in keys and generally used for separating closely related forms, include the following: shape and armature of rostrum, shape of hand and armature of various segments of chela, shape of antennal scale, width of areola, ratio of lengths of anterior and posterior portions of carapace, shape of epistome and shape of seminal receptacle.

The seminal receptacle (annulus ventralis). The seminal receptacle which, among crayfishes, is present only in the Cambarinae, was first reported to function as such by Andrews (1895: 869-870). Hagen (1870) first called attention to the structure and noted its differing shape in the various species of the then inclusive *Cambarus*. Hagen (1870: 20) doubtfully postulated that the seminal receptacle, which he called the annulus ventralis, might function in secreting the cement by means of which the eggs are fastened to the pleopods. The varying shapes of the ridges, sinus, tubercles and fossa of the receptacle are now commonly used to differentiate closely related species of which the females might otherwise, in the present state of crayfish taxonomy, be indistinguishable. However, "As things now stand, an isolated female which does not belong to a species that is very familiar to the taxonomist, generally goes unnamed, and often cannot be determined as to genus." (Hobbs 1942a: 340).

Andrews has extensively studied the seminal receptacle and has published on its ontogeny (1906c) and its morphology in the adult (1906b). He has also pointed out that in *Orconectes limosus*, *O. virilis*, *Cambarus b. bartoni* and *Procambarus clarki*, the receptacle

occurs in two forms, one a mirror image of the other, a fact not generally mentioned in taxonomic works, but one that should be remembered by anyone attempting to identify female Cambarinae. In a species such as *C. robustus* there is a ridge of the receptacle which in one of the two forms runs somewhat obliquely to the animal's right

TABLE 1

Crayfishes for which quantitative data are available for the occurrence of left- and right-handed seminal receptacles

SPECIES	LOCALITY	NO. FEMALES EXAMINED	NO. RIGHT HANDED	NO. LEFT HANDED	AUTHORITY
<i>Procambarus clarki</i> ¹	New Orleans, La.	29	16	13	Andrews (1906b: 465)
<i>Cambarus b. bartoni</i>	Baltimore Co., Md.	12	8	4	Andrews (1906b: 468)
<i>C. robustus</i>	11 localities in vicinity of Ithaca, N. Y.	109	84	25	Author
<i>Orconectes limosus</i>	not given	..	majority	few	Andrews (1906b: 443)
	not given	41	38	3	Andrews (1906c: 131)
	two localities in Catatonk Creek, Tioga Co., N. Y.	39	30	9	Author
<i>Orconectes virilis</i> ²	from Chicago markets	25	4	21	Andrews (1906b: 459)
<i>Orconectes immunis</i> ³	Cornell Univ. Fish Hatchery Ponds, Tompkins Co., N. Y.	137	135	2	Author

¹ Not present in New York State.

² After making certain assumptions regarding the homologies of component parts of the seminal receptacles of *Cambarus virilis* (= *Orconectes virilis*) and *C. affinis* (= *O. limosus*), Andrews (1906b: 461) says, "On these assumptions a right-handed *C. virilis* would be fundamentally like a left-handed *C. affinis* and in both species these seem to be the rarer form."

³ Andrews (1906b) studied the receptacle of *O. immunis*, but, although he did not report left-handed forms, neither did he specifically state nor even definitely infer that he searched for them. He does say, however, (Andrews 1906b: 477), "The inversion of symmetry in the annuli of different individuals may well be general in *Cambarus* [= family Cambarinae]."

and then dips dorsad into a cavity or fossa. This, Andrews (1906*b* and 1906*c*) calls a right-handed seminal receptacle. In the left-handed form the ridge runs obliquely to the animal's left and then dips into the fossa. Plate 2, figures 3 and 4 show these two receptacle shapes. Table 1 summarizes the available published information and adds new data concerning the relative abundance of the two shapes in various crayfish species.

The occurrence of the two receptacle forms presents an interesting problem in genetics which, at least as regards rearing a suitable animal in captivity, should not be difficult of solution. Andrews (1907: 68) states of *O. limosus*, "...there would seem to be no obstacle to the establishment of a permanent race of domesticated crayfish bred in captivity." It is also a question whether or not the male acts differently toward the two forms of the receptacle.

Aside from the phenomenon of the two mirror-image forms, however, Andrews suggests other interesting speculations relating to the seminal receptacle. Are the stylets of the male, and the female receptacle closely adjusted to one another in each species or not? If so, how then does it happen that the receptacles in two species such as *C. b. bartoni* and *O. immunis* are so similar when the stylets of the male are so different? Of what survival value is the seminal receptacle, a structure present only in the more advanced of the two subfamilies of the Astacidae, the subfamily Cambarinae, and yet a structure which has been evolved independently in this subfamily and in the marine genus (of the family Nephropsidae) *Homarus*? These questions are not answered in this paper, but are presented to demonstrate how little is yet known of the natural history of crayfishes, even in the relatively well-worked subject of crayfish reproduction.

Key to Adults of Crayfishes Known from New York

The following key is designed to separate mature New York crayfishes without reference to copulatory stylets or to seminal receptacles. The male I stylets are usually the best diagnostic feature of a species and it is preferable that, if form I males are present, their stylets be used in making the identification by comparing them with the stylet figures on plates 2-4.

Form II stylets are less distinctive and the seminal receptacles are in some species confusingly similar. It is for the identification of form II males and females that the key will be most useful. Reference may then be made to the appropriate figures on plates 2-5.

The identification of immature specimens should not be attempted by the nonspecialist. Shapes of various structures, particularly the

rostrum and hand, are different in immature and in mature individuals. The key has not been designed to include immatures. The minimal known carapace lengths of sexually mature individuals are listed in table 2. Because some immature individuals are known to exceed these values, it would be well to add one or two millimeters to each value and to key no specimens smaller than this.

TABLE 2

Minimal carapace lengths in mm. of sexually mature crayfishes in New York

	MALE	FEMALE
<i>Procambarus b. blandingi</i>	31-32(?)	31-32(?)
<i>Orconectes immunis</i>	23.2	23.0
<i>Orconectes virilis</i>	probably similar to <i>O. immunis</i>	
<i>Orconectes limosus</i>	23.5 (approx. 19 mm. in Penna.; Ortmann, 1906:477)	22.5
<i>Orconectes p. propinquus</i>	16.2	16.5
<i>Orconectes obscurus</i>	19.9	23.1 (approx. 20 mm. in Penna.; Ortmann, 1906:471)
<i>Cambarus b. bartoni</i>	18.5	(approx. 24 mm. in N. J.; Ortmann, 1906:486)
<i>Cambarus robustus</i>	31.7	31.2

The ratio, length of areola / width of areola, used in the first pair of alternatives (A and AA) in the key, is based on measurements of the few mature New York specimens of *O. virilis* and *P. b. blandingi* in my personal collections or in NYSM 6976 (stream survey collections). Of the other six species, 30 specimens each were measured (half males and half females). The critical figure (9.6) is the mean of two values: (1) the smallest ratio (11.4) obtained for the three species in the first division of the key, A; (2) the largest ratio (7.9) obtained for the five species in the second division, AA. The measurement of areola width cannot be made with dividers with sufficient accuracy. It must be made under magnification with an ocular micrometer, or better, with a camera lucida, marking the limits of the narrowest part of the areola on paper and dividing the measurement of this by the power of magnification.

- A. The ratio, length of areola/width of areola, greater than 9.6; a narrow areola usually permitting no more than two punctations to occur side-by-side in its narrowest portion.

- B. Carapace covered with tubercles of such height that the surface feels definitely granular.
 *Procambarus b. blandingi*.
- BB. Surface of carapace smooth except for low tubercles on lateral surfaces of anterior portion and except for setae.
 C. Movable finger (dactyl) of hand with a notch at its base on the inner side. *Orconectes immunis*
 CC. Inner side of movable finger of hand straight.
 *Orconectes virilis*
- AA. The ratio of length to width of areola, less than 9.6; areola relatively broad, permitting at least three punctations to occur in a horizontal row in its narrowest portion.
 B. Rostrum with spines (often only tubercles in large specimens) at base of acumen.
 C. Lateral surface of carapace ahead of cervical groove with two or more sharp spines.
 *Orconectes limosus*
 CC. Lateral surface of carapace ahead of cervical groove with tubercles only.
 D. Rostrum usually with a distinct median carina. Distal margin of ventral surface of carpus of chela usually without either spine or tubercle. *Orconectes p. propinquus*
 DD. Rostrum usually without median carina. Distal margin of ventral surface of carpus of chela with tubercle and usually a spine. *Orconectes obscurus*
- BB. Margins of rostrum not interrupted by spines.
 C. Inner margin of palm with a single row of low tubercles; hand inflated, without conspicuous depression near outer margin (plate 1, figure 6). Rostrum tapering acutely to its tip (plate 1, figure 2). Areola with relatively few large punctations, tending to fall into three cephalocaudal rows (plate 1, figure 3). Carapace without lateral spines. Inner border of antennal scale usually directed rather abruptly caudad (plate 1, figure 2).
 *Cambarus b. bartoni*
 CC. Inner margin of palm with two rows of low tubercles; hand with depression, visible both from the dorsal and ventral sides, near its outer margin (plate 1, figure 5). Rostrum tapering less abruptly to its tip (plate 1, figure 1). Areola with smaller more numerous punctations which do not tend toward an arrangement in three rows (plate 1, figure 4). Carapace often with lateral spines. Inner border of antennal scale usually directed mesiad before turning caudad (plate 1, figure 1)
 *Cambarus robustus*

PLATE 1

Illustrations of structures used to distinguish between *Cambarus b. bartoni* and *Cambarus robustus*.

Cambarus b. bartoni, male I; carapace length 33.5 mm.; DWC 59; N. Y., Tompkins County, Buttermilk Creek at outlet of Treman Lake; coll. by DWC, Sept. 17, 1950. A copulatory stylet of this specimen is drawn on plate 2, figure 5.

Figure 2. Dorsal view of head region showing rostrum, eye and antennal scale

Figure 3. Areola, showing punctations

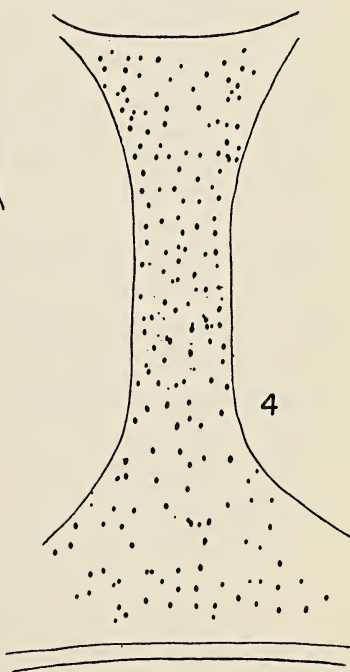
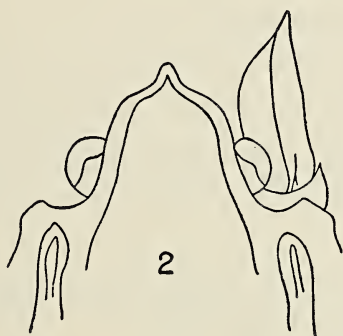
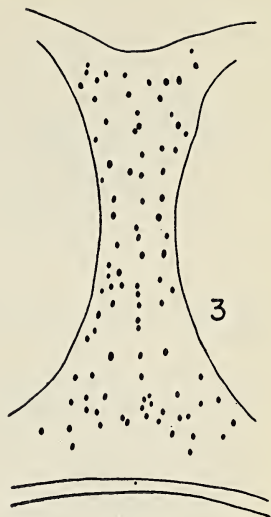
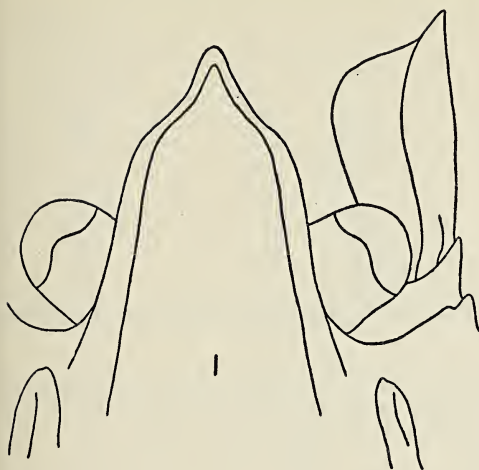
Figure 6. Dorsal view of hand and fingers of left chela

Cambarus robustus, male I; carapace length 50.0 mm.; DWC 12; N. Y., Schuyler County, tributary of Taughannock Creek, 1.4 miles N. W. of Perry City; coll. by R. D. Suttkus, Oct. 8, 1949.

Figure 1. Dorsal view of head region showing rostrum, eye and antennal scale

Figure 4. Areola, showing punctations

Figure 5. Dorsal view of hand and fingers of right chela



Figs. 1-4

0 1 2 3 mm.

Figs. 5, 6

0 1 2 cm.

PLATE 2

Copulatory stylets and seminal receptacles of *Cambarus b. bartoni* and *Cambarus robustus*.

Figures 1-4. *Cambarus robustus*; DWC 91; N. Y., Oswego County, Oswego River drainage, Scriba Brook (a tributary of Oneida Lake) at N. Y. State Fish Hatchery dam at Constantia; coll. by R. L. Wigley, May 6, 1951.

Figure 1. Stylet of male I; carapace length 41.5 mm. A photograph of this specimen appears in the frontispiece.

Figure 2. Stylet of male II; carapace length 38.7 mm.

Figure 3. Right-handed seminal receptacle of female; carapace length 41.0 mm.

Figure 4. Left-handed seminal receptacle of female; carapace length 41.8 mm.

Figure 5. *Cambarus b. bartoni*, stylet of male I; carapace length 33.5 mm.; DWC 59; N. Y., Tompkins County, Buttermilk Creek at outlet of Treman Lake; coll. by DWC, Sept. 17, 1950. Figures 2, 3 and 6 on plate 1 are drawn from this same specimen.

Figure 6. Same, stylet of male II; carapace length 30.0 mm.; DWC 28; N. Y., Tompkins County, Oswego R. drainage, Fishkill Creek in Robert Treman State Park at Enfield; coll. by DWC, June 5, 1950.

Figure 7. Same, seminal receptacle of female; carapace length 31.7 mm.; DWC 77; same locality as figure 5; coll. by DWC, April 22, 1951.

All stylets are right stylets seen in lateral view.



1



2



3



4



5



6



7

0 1 2 3 mm.

PLATE 3

Copulatory stylets of three New York species of *Orconectes*.

Figure 1. *Orconectes p. propinquus*, male I; carapace length 36.5 mm.; DWC 108; N. Y., Herkimer County, Black River drainage, outlet of Fulton chain of lakes at town of Old Forge; coll. by DWC and J. A. Gustafson, May 19, 1951.

Figure 2. Same, male II; carapace length 27.7 mm.; DWC 33; N. Y., Tompkins County, Oswego River drainage, Fall Creek at McLean; coll. by DWC, June 21, 1950.

Figure 3. *Orconectes limosus*, male I; carapace length 43.5 mm.; DWC 20; N. Y., Ulster County, Hudson River drainage, Esopus Creek near W. city limits of Kingston; coll. by Theodore Weyhe, Feb. 18, 1950.

Figure 4. Same, male II; carapace length 27.4 mm.; DWC 132; N. Y., Columbia County, Hudson River drainage, Kinderhook Creek between Valatie and Kinderhook; coll. by J. A. Gustafson and Earl Deubler, Jr., June 1, 1951.

Figure 5. *Orconectes obscurus*, male I; carapace length 32.0 mm.; DWC 94; N. Y., Cattaraugus County, tributary of Allegheny River, 5.4 miles W. of town of Allegheny; coll. by C. R. Robins, May 12, 1951.

Figure 6. Same, male II; carapace length 36.6 mm.; DWC 140; N. Y., Chautauqua County, Allegheny River drainage, W. branch of French Creek, 1 mile N. of town of Findley Lake; coll. by John G. New, June 15, 1951.

All are right stylets seen in lateral view. A photograph of the specimen from which the stylet shown in figure 1 was taken appears in the frontispiece along with a photograph of a form I male of *O. limosus* (carapace length 44.7 mm.) from the same collection as figure 3.



0 1 2 3 mm.

PLATE 4

Copulatory stylets of two *Orconectes* species and of *Procambarus b. blandingi*.

Figure 1. *Orconectes virilis*, male I; carapace length 43.9 mm.; DWC 170; N. Y., Saratoga County, Hudson River drainage, stream (probably Kayaderosseras Creek) at bridge on U. S. Route 9, 2.3 miles S. of city limits of Saratoga Springs; coll. by DWC, Aug. 19, 1952.

Figure 2. Same, male II; carapace length 36.5 mm.; same collection as figure 1.

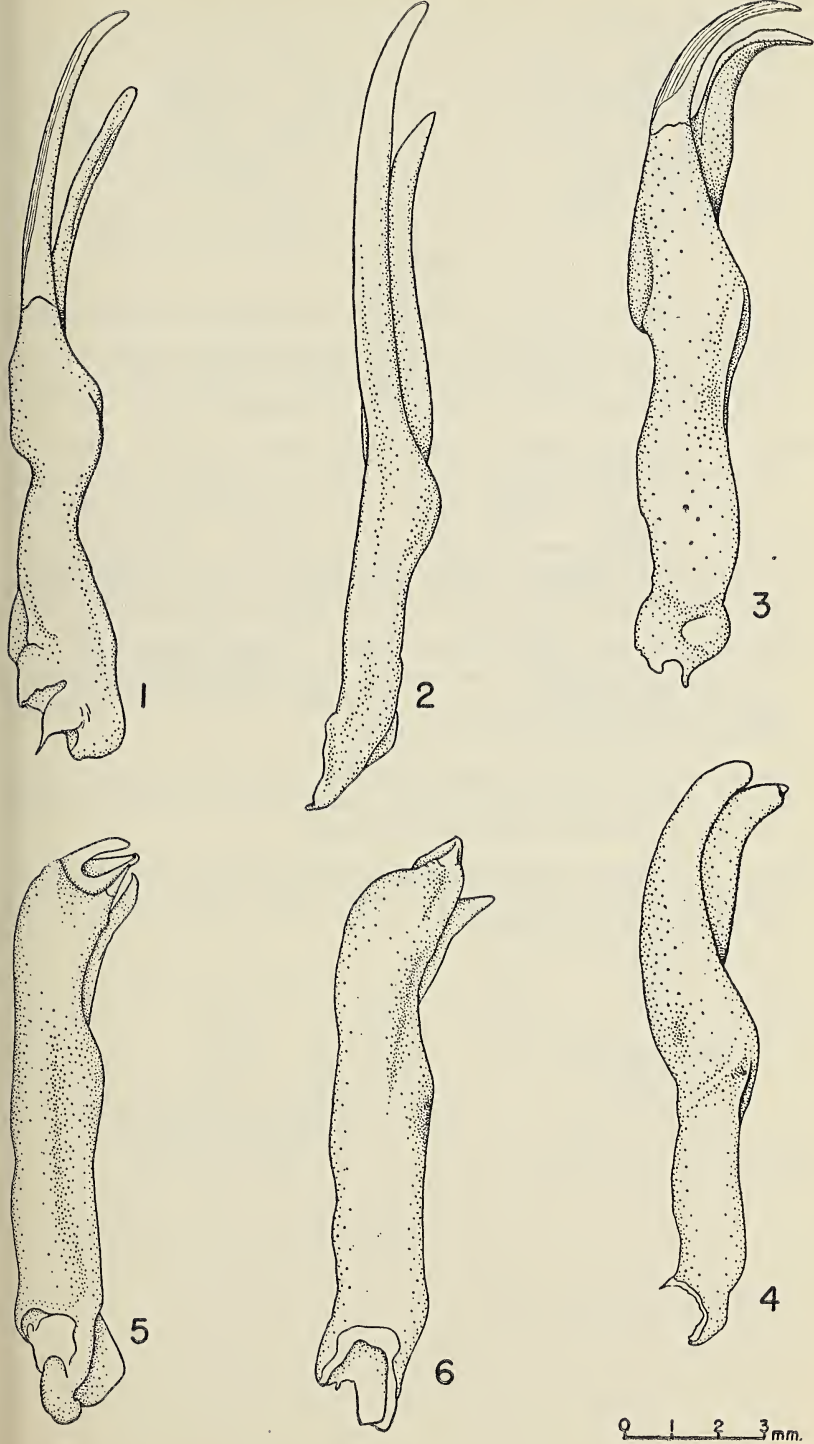
Figure 3. *Orconectes immutis*, male I; carapace length 36.8 mm.; DWC 75b; N. Y., Tompkins County, Oswego River drainage, ponds at Cornell University Experimental Fish Hatchery; coll. by Milton Potash and L. C. Cole, April 13, 1951.

Figure 4. Same, male II; carapace length 38.2 mm.; DWC 138; N. Y., Cayuga County, Oswego River drainage, Duck Lake outlet at town of Spring Lake; coll. by E. C. Raney, May 20, 1951.

Figure 5. *Procambarus b. blandingi*, male I; carapace length 42.8 mm.; DWC 173; N. Y., Westchester County, Bronx River at White Plains North Railroad Station; coll. by DWC, Aug. 25, 1952.

Figure 6. Same, male II; carapace length 45.5 mm.; same collection as figure 5.

All are right stylets seen in lateral view. Photographs of the specimens from which the form I stylets were taken appear in the frontispiece.



0 1 2 3 mm.

PLATE 5

Seminal receptacles of the New York species of *Orconectes* and *Procambarus*.

Figure 1. *Orconectes p. propinquus*; carapace length 35.6 mm.; DWC 108; N. Y., Herkimer County, Black River drainage, outlet of Fulton chain of lakes at town of Old Forge; coll. by DWC and J. A. Gustafson, May 19, 1951.

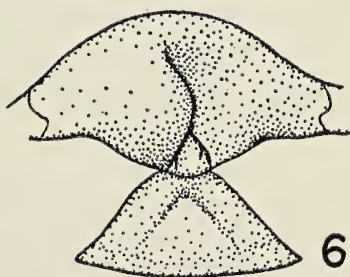
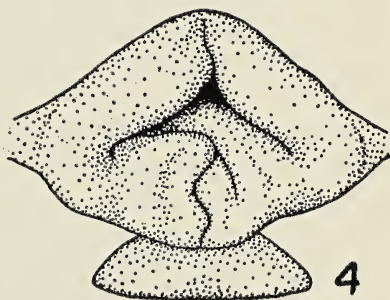
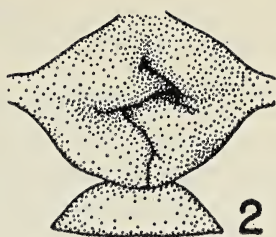
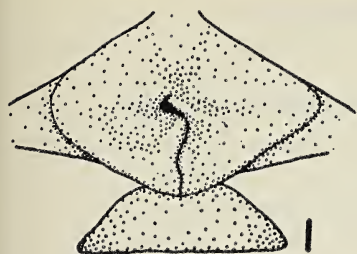
Figure 2. *Orconectes obscurus*; carapace length 28.3 mm.; DWC 140; N. Y., Chautauqua County, Allegheny River drainage, W. branch of French Creek, 1 mile N. of town of Findley Lake; coll. by John G. New, June 15, 1951.

Figure 3. *Orconectes immunitis*; carapace length 39.5 mm.; DWC 72 (specimen no. 15); N. Y., Tompkins County, Oswego River drainage, ditch tributary to Cayuga Inlet in Ithaca; coll. by H. Evans and R. D. Suttkus, July 17, 1950.

Figure 4. *Orconectes virilis*; carapace length 38.1 mm.; DWC 170; N. Y., Saratoga County, Hudson River drainage, stream (probably Kayaderosseras Creek) at bridge on U. S. Route 9, 2.3 miles S. of city limits of Saratoga Springs; coll. by DWC, August 19, 1952.

Figure 5. *Orconectes limosus*; carapace length 45.1 mm.; DWC 20; N. Y., Ulster County, Hudson River drainage, Esopus Creek near W. city limits of Kingston; coll. by Theodore Weyhe, Feb. 18, 1950.

Figure 6. *Procambarus b. blandingi*; carapace length 44.6 mm.; DWC 173; N. Y., Westchester County, Bronx River at White Plains North Railroad Station; coll. by DWC, Aug. 25, 1952.



0 1 2 3 mm.

DESCRIPTIONS

Procambarus blandingi blandingi (Harlan)

(FRONTISPIECE; PLATE 4, FIGURES 5 AND 6; PLATE 5, FIGURE 6)

Astacus blandingi Harlan, 1830: 464-465.*Astacus* (*Cambarus*) *blandingi* Harlan. Erichson 1846: 98, 99.*Cambarus blandingi* Harlan. Hagen 1870: 43-45; pl. I, figs. 63 and 64; pl. III, figs. 140a, b and c.*Cambarus acutus* Girard var. B. Hagen, 1870: 36, 37, 39; pl. III, figs. 144a, b and c.*Cambarus acutus* Girard. Abbott 1873: 80-84.*Cambarus* (*Cambarus*) *blandingi* (Harlan). Ortmann 1905a: 96-97.*Cambarus* (*Ortmannicus*) *blandingi* (Harlan). Fowler 1912: 340, 341, pls. 106, 107.*Cambarus blandingi acutus* Harlan (in part). Faxon 1914: 367.*Procambarus blandingi blandingi* (Harlan). Hobbs 1942a: 341, 342.(not) *Cambarus blandingi* (Harlan). Girard 1852: 91 (authority of Hagen 1870: 45).

Taxonomic remarks: The record of *C. b. acutus* from Fulton County, Md. (Faxon 1914: 367) should be referred to *P. b. blandingi* on the basis of the locality. Hagen (1870: 45) believes that the record of *C. blandingi* from Summerville, S. C., given by Girard (1852: 91), is *C. troglodytes* (= *Procambarus troglodytes*). Harlan (1835) repeats his original description and provides a figure.

It has been pointed out by Hobbs (1942b: 94) that many of the references to this species in the literature are unreliable and that the *blandingi* complex is in need of considerable work before the relationships among the various taxonomic forms are clearly understood.

Type: "Acad. Nat. Sci. Philad. (1 male)." Faxon (1914: 413).

Type locality: "Marshes and rivulets, Southern United States [Camden, Kershaw Co., S. C.]." Faxon (1914: 413). Square brackets are Faxon's.

DESCRIPTION

By touch alone the tuberculated surface of the carapace separates this crayfish from the other New York species.

Male I. The following description is based on the only form I male in NYSM 1936: 3576, from New York, Westchester County, East River drainage, Bronx River. For terminology and method of taking measurements see Hobbs (1942b: 24, text figure b). The description is designed so that comparisons may be made between these specimens and the excellent descriptions of the holotype and

paratypes of *P. b. cuevachicae* (Hobbs 1941: 1-4). Because *P. b. blandingi* has not been adequately described, the following description is given in detail:

Carapace evenly tuberculated except on dorsal surface of anterior portion (ahead of cervical groove) where tubercles are lacking. Postorbital tubercles directed somewhat laterad which, together with the mesially directed bases of the postorbital ridges, present a lyre-shaped figure. Areola narrow, bearing a single row of punctations in its narrowest portion. Single, small lateral spine on each side of carapace.

Rostrum elongate and concave, lateral margins sharp. Broad at base, margins slightly convex just distad of base, tapering gradually to a short, but not broad, acumen. Small spines at base of acumen. Margins of acumen densely setose. Rostral surface sparsely punctate at base, non-setose except for a row of setae just inside lateral margins.

Antennal scale bearing a small spine at distal end of lateral border. Very short anterior margin, bending at about a 45-degree angle to form the antero-mesial border which in turn bends near the antero-posterior midpoint of the scale to form a postero-mesial border. The antero-mesial and postero-mesial borders are about equal in length.

Epistome sagittiform, margins slightly elevated, lacking tubercle on median cephalic border, slight depression in midline at base.

Flagellum of right antenna reaches to midway on posterior section of telson. Distal third hairlike in thinness.

Right chela long and relatively slender. Dorsal and ventral surfaces of propus with few low tubercles. These increase in number and slightly in diameter, but not in height, toward the outer margin. The row of low tubercles on the outer margin is transformed gradually into a row of setiferous punctations on the immovable finger. Toward the inner margin there is a similar increase in number and diameter and a great increase in height. The highest form a row of seven on the exact mesial margin.

Immovable finger (of propus) of right chela with a shallow longitudinal furrow on both dorsal and ventral sides running laterad of the midline and bearing setiferous punctations. A row of 15 tubercles extends from the base of the immovable finger to slightly less than halfway from the tip. This row is situated slightly dorsad of the mesial border. The third tubercle (from the base) is much larger than the others. Slightly ventrad of the mesial border in the distal third of the immovable finger is a row of three tubercles, the most distal being largest. When the fingers are apposed, the proximal enlarged tubercle lies on the dorsal side of the movable finger and the distal enlarged tubercle on the ventral side.

Movable finger (dactyl) of right chela sigmoid, bearing tubercles on basal third, the largest three form a row on the lateral margin. Just dorsal and just ventral to the mesial border is a row of tubercles, the dorsal row containing 21, the ventral row 9. The second tubercle in the ventral row is conspicuously enlarged. The meeting surfaces of both the movable and immovable fingers are flattened and bear, particularly on their distal halves, a dense pile of flattened, bladelike setae.

Carpus of right chela lacking tubercles on lateral border and on lateral halves of dorsal and ventral surfaces except for a single tubercle at a peak of the distal edge on the ventral side about midway between the midline and the lateral margin. Of the tubercles on the remaining surfaces, the two largest are situated, one on the distal edge on the ventral side at the midline, the other on the mesial surface. A shallow, slightly arcuate furrow is present on the dorsal side.

Merus of right chela with mesial and lateral surfaces free of tubercles except on the distal third of the mesial side where they are weakly developed. On the narrow dorsal surface there are 18 tubercles arranged in a single row proximally, but tending toward two rows in the distal half. On the slightly wider ventral surface are two tubercle rows, one mesial and one lateral, with 22 somewhat irregularly aligned tubercles in the former and 14 in the latter. Three small tubercles on the ventral side diverge from the lateral row and follow proximally the lateral arm of the U-shaped distal edge. The end of the arm possesses a well-developed tubercle with a corneous tip.

Anterior section of **telson** with each postero-lateral corner ending in a spine. A second spine occurs on each side mesiad of the corner spine.

Copulatory stylets terminating in four distinct elements (see plate 4, figure 5 drawn from a different specimen), reaching a point just cephalad of caudal border of coxae of third pereopods when the abdomen is flexed. The cephalic process, central projection and caudal process are corneous. Mesial process not so. All elements are gently curved so that the tips are directed laterad. A conspicuous knob at the base of the cephalic process bears a dense cluster of long setae.

Hooks on ischia of third and fourth pereopods. Coxae of fourth pereopods bearing a large, slightly compressed knoblike protuberance.

Measurements: The following measurements in mm. were made on the form I male described above:

Carapace, greatest height — 20.6; greatest width — 22.8; total length — 47.5; length of cephalic section — 31.3

Areola length — 17.1; width — 1.4

Rostrum, width at base — 7.6; length — 11.9

Abdomen length — 42.9

Right chela, length of inner margin of palm — 18.4; width of palm — 14.8; length of outer margin of hand — 51.1; length of movable finger — 29.5

Male II. Plate 4, figure 6 shows a form II stylet from DWC 173 (Bronx River). As compared with the form I stylets, the four terminal elements are not corneous and are shorter, more rounded and softer.

Female. This description is based on the only female in USNM 74,747, from New York, Westchester County, East River drainage, Bronx River. Similar to male I, but chelae proportionately much smaller and less elongate; tubercle count different. Fingers with only a single row of tubercles on the opposable margin of each. Movable finger of hand with conspicuous notch at base of mesial border.

Seminal receptacle (see plate 5, figure 6 drawn from a different specimen) subovate with three tubercles; left, right and caudal. Right tubercle much higher than the other two and curved to the left, creating a deep fossa. Left tubercle gives rise to a ridge which runs to the right on the floor of the fossa and which is largely hidden from view by the overhang of the right tubercle. At the caudal border the sinus originates to left of caudal tubercle. It curves to the right following the caudal edge of the above mentioned ridge and disappears under the overhang of the right tubercle. I am not able to detect its reappearance at the cephalic border of the receptacle. It is very different from the figure given by Hobbs (1941: 3, text fig. 1G) for *P. b. cuevachicae*; more similar to, but still different from the figures given by Turner (1926: 195, pl. xx, fig. 25) and Pearse (1910: pl. I, fig. B) for *P. b. acutus*.

***Orconectes virilis* (Hagen)**

(FRONTISPICE; PLATE 4, FIGURES 1 AND 2; PLATE 5, FIGURE 4)

Cambarus virilis Hagen, 1870: 63-65.

Cambarus debilis Bundy, 1876: 24 (authority of Faxon 1885b: 97).

Cambarus couesi Streets, 1877: 803 (authority of Faxon 1885b: 97).

Cambarus (*Faxonius*) *virilis* Hagen. Ortmann 1905a: 107.

Orconectes virilis (Hagen). Hobbs 1942a: 352.

Types: "Types, M. C. Z., No. 1,151; paratypes, M. C. Z., Nos. 194 and 203 (Lake Superior), No. 196 (Quincy, Ill.), No. 3,342 (Lake Winnipeg), No. 3,343 (Red River of the North), No. 3,344 (Saskatchewan River); Mus. Hist. Nat. Paris (Lake Superior); Wurzburg Mus. (Lake Superior); Australian Mus., Sydney." Faxon (1914: 420). I have examined the types and the MCZ paratypes.

Type locality: Lake Superior; designation by Faxon (1914: 420).

DESCRIPTION

The best description of this species is that given by its author, Hagen (1870: 63-64). Because I have seen so few specimens from New York (tables 16, 17 and 18), no account of the extent of its variation can be given.

It is readily separated from *Orconectes immunis*, the crayfish which in New York is most similar to it, by the presence in *O. immunis* of a notch at the inner base of the movable finger. The rostral shape is also different, *O. virilis* having straighter sides, a longer acumen and a more shallow excavation in the middle than has *O. immunis*. The shapes of first form stylets should readily separate these two species (plate 4, figures 1 and 3). The male I stylets in *O. virilis* reach just to the caudal border of the bases of the chelae when the abdomen is flexed, while those of *O. immunis* reach only to a point just cephalad of the caudal border of the second pereopods.

The male II stylets (plate 4, figures 2 and 4) and the seminal receptacles (plate 5, figures 3 and 4) are also different, but less obviously so.

Orconectes immunis (Hagen)

(FRONTISPIECE; PLATE 4, FIGURES 3 AND 4; PLATE 5, FIGURE 3)

Cambarus immunis Hagen, 1870: 71-73 (in part only, authority of Faxon 1885b: 100).

Cambarus signifer Herrick, 1882: 253 (authority of Faxon 1885b: 99).

Cambarus immunis spinirostris Faxon, 1885a: 146.

Cambarus (*Faxonius*) *immunis* Hagen. Ortmann 1905a: 113.

Faxonius immunis immunis (Hagen). Creaser 1933a: 13.

Faxonius immunis pedianus Creaser, 1933a: 14-16.

Orconectes immunis immunis (Hagen). Hobbs 1942a: 352.

Types: "Types, M. C. Z., No. 188; paratypes, M. C. Z., No. 3,355 (Belleville, Saint Clair Co., Ill.); Mus. Hist. Nat. Paris (Lawn Ridge, Ill., 1 male)." Faxon (1914: 421).

Type locality: Lawn Ridge, Illinois; designated by Faxon (1914: 421).

Taxonomic remarks: I agree with Creaser (1931: 262 and 1933a: 13-14) and Ortmann (1931: 93, 94) that *C. i. spinirostris* is but a variant form. See also Rhoades (1944a: 132, 133). Williams and Leonard (1952: 1003-1005) present data which indicate that Creaser's *O. i. pedianus* is but one extreme of a clinal variation.

DESCRIPTION

O. immunis is a pond crayfish which is often called the "grass-crab" or "butter-crab" by bait dealers and fishermen. The latter name may be due to its smooth surface which is often slippery, particularly in newly moulted specimens.

The most detailed description of this species is the one given by its author (Hagen 1870: 71-73). The characters which separate it from *O. virilis*, the only New York species likely to be confused with it, are given under the description of *O. virilis*.

***Orconectes propinquus propinquus* (Girard)**

(FRONTISPIECE; PLATE 3, FIGURES 1 AND 2; PLATE 5, FIGURE 1)

Cambarus propinquus Girard, 1852: 88.*Cambarus (Faxonius) propinquus* Girard. Ortmann 1905a: 107.*Faxonius propinquus* (Girard). Creaser 1933b: 4.*Orconectes propinquus propinquus* (Girard). Hobbs 1942a: 352.

Types: Hagen, in preparing his monograph, borrowed what he called Girard's "types" from William Stimpson (Hagen 1870: 7), and gave figures in his monograph of the first and second form copulatory stylets. It is to be remembered, however, that in 1870 the word "types" did not necessarily have the connotations which it has today. The word merely meant specimens identified by some student of the group, the specimens then being called that person's types of a given species. Whether or not Hagen saw specimens of *O. p. propinquus* which came from a locality listed by Girard, which were used by Girard in writing his original description and which we would now call strictly Girard's types, cannot be known. Hagen does not give localities for the specimens figured.

It is generally believed that Hagen returned the specimens to Stimpson and that they, along with the majority of Girard's material from which a neoholotype might be selected, were destroyed in the great Chicago fire of 1871 (Faxon 1914: 417). At least, at present they cannot be located.

There is a specimen of *O. p. propinquus* in the Academy of Natural Sciences of Philadelphia which has Girard's name on the label followed, however, by a question mark (Hagen 1870: 7; Faxon 1914: 417). This specimen is from Garrison Creek, Sackett's Harbor, N. Y., a locality given by Girard. In view of the fact that Girard's name is followed by a query, that there is a single specimen and that the identity of Garrison Creek is not certain (see below), this is probably not suitable material from which to select a type. Apparently, there are no specimens now in existence of *O. p. propinquus*, which are known with certainty to have been identified as such by Girard, nor have new types been selected.

Type locality: The following three localities are given by Girard (1852:88):

1. "Lake Ontario, four miles from the shore, opposite to Oswego [Oswego Co., N. Y.], found in the stomach of *Lota maculosa*."
2. "Garrison Creek, Sacketts Harbor [Jefferson Co., N. Y.]."
3. "Four Mile Creek, Oswego [Oswego Co., N. Y.]."

The first locality is listed (as Oswego, Oswego County, N. Y.) as type locality by Ortmann (1906: 363) without selection of new types.

The second locality is given (again without a selection of new type specimens) as the type locality by Faxon (1914: 417) along with locality number 3. After consulting numerous old maps, county histories and gazetteers of Jefferson County, N. Y., I am unable to locate Garrison Creek. It is probable that the stream intended is the one known to the inhabitants of Sacketts Harbor and in the literature as Mill Creek. There is a garrison (Madison Barracks) at its mouth. It is not possible at present, however, to demonstrate conclusively that the two stream names are synonymous.

I have not visited Four Mile Creek nor do I know of existing collections from it. It appears that the first locality as listed by Ortmann is the type locality. This subspecies is described in a comparison between it and *O. obscurus* (given under *O. obscurus*). Hybridization of *O. p. propinquus* is discussed under that heading as a separate section of the study.

***Orconectes obscurus* (Hagen)**

(PLATE 3, FIGURES 5 AND 6; PLATE 5, FIGURE 2)

Cambarus obscurus Hagen, 1870: 69, 70.

Cambarus propinquus var. *obscura* Hagen. Faxon 1885b: 92-94.

Cambarus obscurus Hagen. Faxon 1898: 652.

Cambarus (*Faxonius*) *obscurus* Hagen. Ortmann 1905a: 107.

Orconectes obscurus (Hagen). Hobbs 1942a: 352.

Cambarus propinquus Girard. Williamson 1901: 13 (authority of Ortmann 1905b: 387, 388).

Cambarus rusticus Girard. Williamson 1901: 13 (authority of Ortmann 1905b: 387, 388).

Types: "Cotypes, M. C. Z. No. 181, 3,353, 3,354; U. S. N. M. No. 4,971; Mus. Hist. Nat. Paris; Wurzburg Mus.; Australian Mus., Sydney." Subsequent designation by Faxon (1914: 418). I have examined the cotypes in MCZ and USNM.

Type locality: Genessee River, Rochester, Monroe County, N. Y. (Hagen 1870: 70).

DESCRIPTIONS OF *Orconectes p. propinquus* AND *O. obscurus*

Ortmann (1906: 358-362, 365-372) has given detailed descriptions for these two species in Pennsylvania and, because my materials are similar, the descriptions here will be limited to pointing out differences between New York State and Pennsylvania populations. These two species are so close morphologically that comparisons between them will be made wherever there appear to be differences.

The possibility of assigning all specimens to one or the other of these two species is probably limited to localities where they do not occur together for, as discussed under a separate heading below,

hybridization appears to occur between them. None of the discussion of these two species under the present heading of "Descriptions" applies to localities where they occur together (figure 5).

Ortmann found the majority of morphological features to be almost identical in these two species. It is in the features which he found best to show differences that my materials appear to vary from Ortmann's. These features are:

1. Presence or absence of a median keel (carina) on the rostrum
2. Armature of carpus of chela
3. Armature of merus of chela
4. Shape of seminal receptacle
5. Shape of copulatory stylets

Rostral carina. Of the rostrum in *O. p. propinquus*, Ortmann (p. 359) says, "Surface concave, with a more or less distinct, low, longitudinal median keel toward the tip." Of *O. obscurus*, he says (p. 369), "Rostrum similar to that of *C. propinquus*, but always without any trace of a median keel." In New York *O. p. propinquus*, the median carina is indeed usually distinct, but some mature or immature specimens in most large collections show hardly a trace of it and it is only by having the rostrum thoroughly dry and the light source properly directed that it can be made out.

Furthermore, occasional specimens of *O. obscurus*, from widely separated localities, show a relatively broad, slightly raised region in the midline of the rostrum, and considering rostrum alone, they could hardly be separated from specimens of *O. p. propinquus* showing minimal development of the carina. Five of 12 specimens of *O. obscurus* on loan from Dr. H. H. Hobbs, Jr., which were taken in Pendleton County, W. V. (Hobbs' collection 7-3149-3a) show a distinct although small median rostral carina.

Presence or absence of rostral carina can not be used as a character for completely separating these two species, even though it will correctly assign to species the majority of individuals.

Armature of carpus of chela. Of the carpus of the chela of *O. p. propinquus* Ortmann (p. 360) says, "Lower surface with a low and broad tubercle in the middle of the anterior margin, which is very rarely subspiniiform. . ." Again (p. 364) he says, "The anterior margin is often without any spine, or even tubercle; there is, however, a low tubercle developed in many cases, and in two cases it was spiniiform. . ." Of *O. obscurus* he says (p. 370), "The *carpopodite* differs from that of *C. propinquus* in the development of a strong tubercle on the anterior margin of the lower side. This tubercle very rarely

is indistinct (chiefly so in regenerated claws); generally it ends in a distinct, stout, conical spine."

New York *O. obscurus* conform with Ortmann's description given above. In *O. p. propinquus*, however, I have several specimens from widely separated localities, with well-developed spines on the lower distal border of the carpus of each chela and a number of others with spines less well developed, often occurring unilaterally. All degrees of development of the tubercle occur, from none at all to one quite distinct. By far the greatest proportion of specimens, however, have no tubercle or one which is at best barely perceptible.

Of these two species, data on hand show that if a specimen has no tubercle or spine on the lower distal border of the carpus, it is *O. p. propinquus*. The presence of a tubercle, however, does not indicate that the specimen is *O. obscurus*. The character will not give complete separation of these species.

Armature of merus of chela. Of the spines on the lower side of the merus in *O. p. propinquus*, Ortmann (p. 364) says that they are generally represented by only two spines, the distal spine of each row being alone present. He then points out his only localities where additional spines occur.

Of *O. obscurus* Ortmann (p. 370) says, "The *meropodite* differs from that of *C. propinquus* by the constant presence of a series of 4-8 small tubercles, or teeth, behind the distal spine on the inner lower margin. These teeth are never wanting in any of my specimens. The outer lower margin has one or two spines. The lat[t]er number is comparatively rare."

New York *O. obscurus* agree with those of Ortmann. In *O. p. propinquus* however, specimens with a distinct row of low spines on the inner lower margin far outnumber those which show only the single distal-most spine. All degrees of variation occur even in single large collections. I have found as many as four spines in the outer row.

Shape of seminal receptacle (plate 5, figures 1 and 2). Ortmann (p. 361) says of *O. p. propinquus* that its seminal receptacle is flat, slightly depressed in the middle, has no tubercles on the anterior margin and (p. 365) that only slight differences due to age are noticeable. He differentiates the receptacle of *O. obscurus* by its having a "well-marked" depression in the middle and two subconical tubercles in the anterior part (p. 371).

New York *O. p. propinquus* differ from this description in that two tubercles frequently occur near the anterior border of the receptacle. The highest of these tubercles are as high as the lowest tubercle found in *O. obscurus*. However, it is always possible to distinguish

the one species from the other, for in *O. obscurus* the whole receptacle is generally more nearly round and the two tubercles are not only more distinctly conical, but are fused at the midline, which has never been seen to occur in *O. p. propinquus*. The shape of the seminal receptacle is then, at least in New York State material, a character which will give complete separation. Unfortunately the differences are qualitative and no way has as yet been found of expressing them in numbers.

Shape of copulatory stylets (plate 3, figures 1, 2, 5 and 6). The first form copulatory stylets of these species are distinguished by Ortmann (p. 365) as follows, "...there is a tendency in the Pennsylvania specimens [of *O. p. propinquus*] toward the development of a slight notch on the anterior margin in the place where *C. obscurus* has a shoulder. . . The notch never assumes the shape of the 'shoulder' of *C. obscurus*, and the sexual organs differ in other respects from the lat[t]er species, chiefly in that the tip of the inner part [mesial process] is never blunt or dilated."

Ortmann had only 18 males I of *O. p. propinquus* and of these, seven had a notch. This appears to be more than a tendency toward its formation. I have not kept a record of numbers of New York State specimens with or without a notch on the stylet, but a large proportion have it. This is true throughout the range in New York of this species and in individual collections.

However, these two species are rapidly separated on the basis of this character, for the notch of *O. p. propinquus* is never more than a suggestion of the well-developed, right-angled shoulder on form I stylets of *O. obscurus*. *O. obscurus* males I have never been observed without the shoulder.

The other stylet character which appears to separate completely these species is the shape of the tip of the mesial process both in form I and form II males. In *O. p. propinquus* the mesial process in both forms of the male ends as a relatively sharp point. In *O. obscurus*, on the other hand, the mesial processes in both form I and form II stylets are rounded off at the tip or are even slightly inflated. A few of my males I of *O. obscurus* from the Allegheny River drainage have the distal quarter of the mesial process directed mesiad at about a 45-degree angle. This appears to be an aberrant shape.

O. p. propinquus appears to be a much more variable species than is *O. obscurus*. See the section "Hybridization" for a discussion of possible hybrids between these two species.

***Orconectes limosus* (Raf.)**

(FRONTISPIECE; PLATE 3, FIGURES 3 AND 4; PLATE 5, FIGURE 5)

Astacus limosus Rafinesque, (Nov.) 1817: 42.*Astacus affinis* Say, (Dec.) 1817: 168.*Astacus* (*Cambarus*) *affinis* Say. Erichson 1846: 96.*Cambarus affinis* (Say). Girard 1852: 87.*Cambarus pealei* Girard, 1852: 87.*Cambarus* (*Faxonius*) *limosus* (Rafinesque). Ortmann 1905a: 107.*Orconectes limosus* (Rafinesque). Hobbs 1942a: 352.*Astacus bartoni* Fabricius. Milne-Edwards 1837: 331.**Types:** "... types not extant." (Faxon 1914: 417).**Type locality:** Designated by Faxon (1914: 417) as: "... the muddy banks of the Delaware River, near Philadelphia, Pennsylvania."**Taxonomic remarks:** Holthuis (1954) quotes Rafinesque's original description in full.

DESCRIPTION

Ortmann (1906: 352-356) has described *O. limosus* in detail. In the materials I have seen from New York there appear to be no differences. It is readily separated from the other New York State species by the presence of at least two spines on each side on the cephalic section of the carapace. These are present even in young immatures. The divergent tips of the copulatory stylets (plate 3, figures 3 and 4) are a constant character which, in both form I and form II males, separates this from the other New York State species. A relatively dense pubescence, particularly on carapace and claws is typical of specimens up to 30 mm. carapace length. In larger specimens it becomes less noticeable.

Apparent hybridization between this species and *O. p. propinquus* is discussed under the heading "Hybridization" in a separate section.

***Cambarus robustus* Girard**

(FRONTISPIECE; PLATE 1, FIGURES 1, 4 AND 5; PLATE 2, FIGURES 1, 2, 3 AND 4)

Cambarus robustus Girard, 1852: 90.*Cambarus bartoni* var. *robusta* Girard. Faxon 1885c: 358.*Cambarus bartoni robustus* Girard. Faxon 1890: 622.*Cambarus* (*Bartonius*) *bartoni robustus* Girard. Ortmann 1905a: 117.*Cambarus* (*Bartonius*) *robustus* Girard. Creaser 1931: 260.*Cambarus* (*Cambarus*) *robustus* (Fabricius). Fowler 1912: 340, 341.*Cambarus bartoni* (Fabricius). Williamson 1905: 310 (authority of Ortmann 1906: 388).**Types:** "Type probably destroyed in the Chicago fire in 1871; paratype (?), Acad. Nat. Sci. Philad. (1 male)." (Faxon 1914: 423).**Type locality:** Humber River, near Toronto, Canada. Subsequent designation by Faxon (1914: 423) from Girard's first-named locality.

Taxonomic remarks: The current restricted use of *Cambarus* (see Hobbs 1942a: 354) makes Ortmann's subgenus *Bartoni* (see synonymy above) identical to it. No subgenera for *Cambarus* (*sensu stricto*) have been proposed.

The opinion of Creaser (indicated in the synonymy above) that *C. robustus* is not a subspecies of *C. bartoni* seems indisputable when the ranges of *C. robustus* and *C. b. bartoni* are compared (figures 6 and 7). The fact that the two can occupy so much territory in common, often the same streams, and still maintain their identity, makes it difficult to conceive of them as subspecies of the same species.

They do, however, have different habitat preferences, which in the case of the mountain stream (headwater) species, *C. b. bartoni*, appear to be rather strict. Assuming *C. b. bartoni* became established first in the New York stream systems which both it and *C. robustus* now occupy together, then perhaps one can view these two taxa as conspecific subspecies living in the same streams, kept fairly well apart by different habitat preferences, but intergrading in those areas where they actually come in contact.

This view does not seem to be supported by the fact that, although 10 percent of localities (29 of 289) from which *Cambarus* was taken produced both *C. robustus* and *C. b. bartoni*, only 14 percent of these 29 (four collections; DWC 35, 92, 95 and 96) contained any specimens which appeared morphologically intermediate. (The single specimen, a female (imm.?), in NYSM 1937: 172 also appears intermediate.) This can be put more strongly by stating that of the 419 specimens of this genus in these 29 collections containing both taxa, only about 2 percent of the individuals (10) appeared intermediate. It seems then that these crayfishes have diverged to the degree that, even when living in the same habitat, they rarely interbreed to produce viable offspring. It is on this basis that I choose, for the moment, to consider these two taxa as belonging to different species. The situation obviously requires detailed study.

I believe that *C. robustus* has its closest affinities with *Cambarus montanus montanus* and its so-called subspecies, *Cambarus montanus acuminatus*, and with *Cambarus bartoni sciotensis* Rhoades.

Of *C. m. montanus*, Faxon (1914: 387) says, "From *Cambarus bartonii montanus* the passage is easy to *C. b. robustus* . . ." Again on p. 388, in speaking of "very nearly typical examples of *C. b. robustus*," from West Virginia, he says, "... they show an approach to *C. b. montanus*, from which the form *robustus* is probably derived."

A comparison of some of my New York *C. robustus* with *C. m. montanus* collections at USNM brings out striking similarities. The resemblances are far closer than between *C. robustus* and *C. b. bartoni* and one is practically compelled by the visual evidence to concede a close relationship between *C. m. montanus* and *C. robustus*.

C. robustus is apparently also close to another *C. montanus* subspecies. Faxon (1885*b*: 68), says that specimens of *C. m. acuminatus* from North Carolina approach *C. robustus*.

C. b. sciotensis types have been examined at the United States National Museum and this form may well turn out to be a subspecies of *C. montanus*. Of his subspecies Rhoades (1944*b*: 97) says, "This subspecies is intermediate between *C. m. montanus* of the Appalachians and the *C. b. robustus* of the St. Lawrence drainage."

C. montanus and *C. b. sciotensis* are in need of considerably more taxonomic study before the relationships between them, and of *C. robustus* to them, can be accurately known.

C. robustus is described in a comparison between it and *C. b. bartoni*, given under *C. b. bartoni*.

***Cambarus bartoni bartoni* (Fab.)**

(PLATE 1, FIGURES 2, 3 AND 6; PLATE 2, FIGURES 5, 6 AND 7)

Astacus bartoni Fabricius, 1798: 407.

Astacus ciliaris Rafinesque, 1817: 42 (authority of Faxon 1914: 423).

Astacus pusillus Rafinesque, 1817: 42 (authority of Faxon 1914: 423).

Astacus affinis Say. Milne-Edwards 1837: 332.

Cambarus bartoni (Fabricius). Girard 1852: 88.

Cambarus (*Bartonius*) *bartoni* (Fabricius). Ortmann 1905*a*: 117.

Cambarus (*Cambarus*) *bartoni* (Fabricius). Fowler 1912: 340, 341.

Type: "(fragment only), Kiel Museum" (Faxon 1914: 423).

Type locality: "Habitat in America Boreali" (Fabricius 1798: 407).

Taxonomic remarks: Milne-Edwards, in confusing *A. affinis* Say with *A. bartoni* Fabricius was apparently misled by a transposition of the figure numbers for these species in Harlan (1835).

The current restricted use of *Cambarus* (Hobbs 1942*a*: 354) makes Ortmann's subgenus *Bartonius* (and Fowler's new name) identical to it. No subgenera for *Cambarus* (*sensu stricto*) have been proposed.

Faxon's list (1914: 423-425) contains 12 subspecies of *C. bartoni*. Some of these have subsequently been considered full species or removed to other species, but all of the 12 are in need of detailed study before their taxonomic status can be at all certain.

Faxon (1885*b*: 65) says that Professor Smith Barton, the collector, lived in Philadelphia and also (Faxon 1914: 423) suggests that the

type locality is probably Philadelphia, but he does not specifically designate a restricted type locality.

I am unable to explain the inclusion by Fowler (1912: 344) of "*Cambarus acutus* (nec Girard) var. b. Hagen" in his synonymy of *C. bartoni*. Hagen's description (1870: 36-37) and his figure of the antennal scale (plate 3, figure 144a) cannot possibly be *C. bartoni* and Hagen himself says that his variety may be *C. blandingi* (Hagen 1870: 37).

Holthuis (1954) reproduces Rafinesque's descriptions of *A. ciliaris* and *A. pusillus*.

COMPARISON BETWEEN *Cambarus bartoni bartoni*
AND *Cambarus robustus*

Ortmann (1906: 377-381, 386-393) gives detailed descriptions for these two species and New York material does not differ. The discussion here is intended to point out the differences between these morphologically similar species. Hybrid individuals probably occur, but are considered elsewhere.

The first character listed in the key is believed to give complete separation. It must be stated, however, that all of my specimens of *C. robustus* have not been checked for the presence of the two rows of tubercles on the inner side of the palm. At first I disregarded this character given by Ortmann, but now believe that I was led astray by the fact that some specimens with regenerated claws were examined and these do not always show it. Subsequent spot checking in numerous collections from a wide range of localities has produced no *C. robustus* with normal claws which lack the two rows (plate 1, figure 5). A regenerated claw can be identified by its greater length of fingers in proportion to palm length and by its being thinner and generally more weakly formed. All of my *C. b. bartoni* have but a single row of tubercles on the inner margin of the palm (plate 1, figure 6).

The depression near the outer margin of the hand in *C. robustus* is always present, even in regenerated claws and in immature specimens. On the dorsal side of *C. b. bartoni* claws there are fewer and larger punctations than in *C. robustus*, and these may sometimes be so closely grouped that they partially fuse. The effect produced is a depression, but the ventral side usually will be fully rounded.

Rostral shapes in the very young of these two species are nearly identical but, as growth proceeds, differences develop resulting typically in the conditions shown on plate 1, figures 1 and 2. Again, however, there appear to be intermediates.

The punctations in the areola are variable in the two species and, although conditions such as are shown in plate 1, figures 3 and 4, leave little cause for doubt, there are other cases where a species determination on the basis of this character alone is hardly possible.

The same may be said for the lateral spine of the carapace. Although all *C. b. bartoni* lack it, not all *C. robustus* possess it and some even lack a tubercle in its place. The newly hatched young of *C. robustus* lack this spine at least up to third stage and its greatest frequency appears to be in individuals between 20 and 30 mm. carapace length.

In plate 1, figures 1 and 2, the shapes of the antennal scale are obviously different, yet measurements of length and width do not show it when a ratio of the two measurements is obtained. Possibly measurements of the angle formed by the cephalic border and the lateral margin will show the difference, but until the range of the variation is shown by measurement, it can hardly be used to give complete separation.

In addition to the characters listed in the key, there are two others which appear to give complete separation. Plate 2, figures 3, 4 and 7, show that where *C. b. bartoni* has the caudal border of the seminal receptacle smoothly rounded, this border, although rounded in *C. robustus*, is less smoothly so. Variants from the figures occur, but I have tested the character by having receptacles of these two species shown me under the microscope. The species were identified previously on the basis of the sum total of their morphology, yet on the basis of receptacle alone the same identifications were made.

Eye size may also be a useful character. The ratio of length of caudal section of carapace to eye diameter in 10 specimens of each species has given complete separation, but many more individuals must be measured before it can be utilized with confidence.

HYBRIDIZATION

HYBRIDIZATION BETWEEN *O. p. propinquus* AND *O. limosus*

I have two specimens which appear to be intermediate between *O. p. propinquus* and *O. limosus*. This is particularly interesting because *O. limosus* is a rather isolated species both geographically and morphologically.

One of the supposed hybrids is a male I, taken from Catatunk Creek at Candor, Tioga County, N. Y. on May 25, 1951 by Dr. E. C. Raney (DWC 139). The collection contains in addition, specimens of *C. b. bartoni* and one form I male each of *O. p. propinquus* and *O. limosus*. A previous collection from this same locality (DWC 16) produced 40 *O. limosus*.

The features which most indicate the possibility of this specimen being hybrid are rostrum, stylets, armature of merus of chela and spines on lateral surface of carapace ahead of cervical groove.

The rostrum has a low median carina. It is definitely a carina, however, not a broad raised area. I have never before observed this *propinquus* characteristic in *O. limosus*. In contrast, the acumen is long, more like *O. limosus*.

The stylets appear distinctly intermediate. The terminal elements are more divergent and shorter than in *O. p. propinquus*. The mesial process is directed more laterad. All these conditions are an approach to *O. limosus*, but the appearance is no more of one species than the other. Measurements have been made of the length of the free tip of the mesial process (*B*) and of the distance from tip of mesial process to orifice (*A*). Only five specimens each of *O. p. propinquus* and *O. limosus* were measured. The ratios of *A/B* are as follows:

<i>O. p. propinquus</i>	2.0 — 2.3, mean 2.1
<i>O. limosus</i>	3.0 — 3.1, mean 3.0
Hybrid (?)	2.6

It will be seen that the hybrid (?) is intermediate as are many hybrids on their measurable characters.

The spines of the inner row of the merus of the left chela are rather long as in *O. limosus*. Those of the right chela are shorter and more like *O. p. propinquus*.

There are two spines on the left side of the carapace ahead of the cervical groove. On the right side, no spines are present but there are several reddish-brown spots which probably represent places where some protuberance has broken off or been worn away.

The general appearance of the specimen is as in *O. p. propinquus*, the pubescence of *O. limosus* being absent.

Intensive collecting in this same area on August 29, 1952 has produced one more male I (NYSM 7014) which appears similarly intermediate. Two collections (NYSM 7006 and 7011) from the Unadilla River (Chenango-Otsego Co., Susquehanna R. drainage) contain both these species, but there are no signs of hybridization.

HYBRIDIZATION BETWEEN *O. p. propinquus* AND *O. obscurus*

The combined descriptions of *O. p. propinquus* and *O. obscurus* show that some of the variations in *O. p. propinquus* tend in the direction of *O. obscurus*. Most of these are found in localities distant from where *O. obscurus* is at present known to occur, and are apparently within the normal range of variation of *O. p. propinquus*, unless perhaps a one-way introgression is occurring. Neither Ortmann (1906) nor Turner (1926) has been able to find hybrids between these species. In fact, I can not find reference to certain hybridization between any crayfish species.

I was unable to find these two species together in the same restricted habitat until 1952 when, knowing the general picture of distribution, I was able to do so in three localities.

Two of these three collections (from localities about 15 miles apart) appear to contain hybrids, for in these collections I am unable to sort out the majority of specimens into one or the other species. Because of this, these two collections are not shown in figure 5. They are:

(1) NYSM 6994 (32 specimens of these two species, including three males I and three females) from New York, Oneida Co., Oswego R. drainage, Fish Creek five miles east of Vienna. This collection also contains *C. robustus*.

(2) NYSM 6996 (109 specimens of these two species; 67 males I and 42 females) from New York, Oneida Co., Mohawk R. drainage, Deans Creek at Westmoreland. This collection also contains *C. robustus* and *O. immunis*.

I am not yet able to show the intermediacy of these supposed hybrids on the basis of measurable characteristics.

Collection NYSM 7022 from Otisco L. outlet, Oswego R. drainage, Onondaga Co., N. Y., contains both species, but none of the specimens appears definitely intermediate. Other recent (1952) collections from this general area inhabited by these two species contain only one or the other species and the majority of specimens sort readily (NYSM 6992, 6993 and 6997).

Hagen (1870: 69) reports a mixed collection of *O. obscurus* and *O. p. propinquus* from Rochester, N. Y. It is not stated whether or not these were from the same restricted locality. I have been able to take only *O. p. propinquus* and *O. immunis* at Rochester (DWC 53, 101), which is unfortunate because Rochester is the type locality for *O. obscurus*.

HYBRIDIZATION BETWEEN *C. robustus* AND *C. b. bartoni*

In the section "Descriptions," under *C. robustus* it is stated that in collections containing both *C. robustus* and *C. b. bartoni*, about 2 percent of individuals appear morphologically intermediate between these two species. These specimens are intermediate in some or all of the four major distinguishing features: hand, areola, rostrum and antennal scale. See the above mentioned section for a brief discussion of the taxonomic status of these two taxa.

LIFE HISTORIES

Orconectes propinquus propinquus

This species has been carefully studied under field conditions at Urbana, Ill. by Van Deventer (1937). The following outline of its life cycle in Illinois, taken from Van Deventer's work, is presented here as a summary of a life history which, at least in its major events, is typical of New York members of the genus except for *O. immunis*.

Briefly, the life of individuals of *O. p. propinquus* at Urbana, Ill. consists of the following events:

1. The young are hatched in May or June and remain attached to the mother for one or two weeks.
2. Following the second moult they become free swimming and measure about 5 mm., carapace length.
3. They undergo a total of 6 to 10 moults between the time of hatching and the end of the first growing season in late September or early October, and attain a carapace length of 12-27 mm.
4. Sexual maturity in both sexes is attained coincident with a carapace length of about 20 mm. and the majority of the season's young become sexually mature by their first fall after hatching.
5. During the winter no growth takes place.
6. Copulation occurs in late fall and early spring.
7. The eggs are laid in late March or early April and are carried for a period of four to six weeks, depending on temperature. As they are laid, the eggs are fertilized by sperm which has been held in the seminal receptacle.
8. The adult males moult twice during the spring or early summer, changing to form II with the first adult moult, and reverting to form I with the second adult moult.
9. The yearling individuals of both sexes which did not become sexually mature at the end of their first summer of life apparently moult four times during their second year. They attain sexual maturity with the second yearling moult.
10. The adult females undergo a single moult immediately following the shedding of the young in spring.
11. Apparently no growth takes place in connection with the first yearling moult, among either mature males or immature individuals; but marked growth occurs in connection with the second yearling moult in both groups.
12. A similar growth takes place as a result of the single moult among the adult yearling females.
13. The portion of the young of the previous year which reached sexual maturity by the end of their first growing season produce a

brood of young the following spring, attain a maximum size of 35-40 mm. carapace length as a result of the second adult moult of the males and the single adult moult of the females, and die as yearlings.

14. The individuals which failed to attain maturity by the end of their first growing season live over a second year, attain maximum size during their second summer, produce a brood of young in the following spring, and for the most part die as two-year-olds.

15. A very few individuals, among which females predominate, survive over a third year, and produce a brood of young in their third spring.

16. With the possible exception of these last few, the individuals of this species apparently produce only a single brood of young during their lives.

TABLE 3

Seasonal data for *Orconectes p. propinquus* in New York

a. Tabulated from all specimens in D. W. Crocker collections 1-158 and in NYSM 6977-7022 (collected in August 1952)

	APRIL	MAY	JUNE	JULY	AUG.	SEPT.	OCT.
male I	49	107	2	83	203	73	63
male II	—	29	27	8	33	1	8
male imm.	1	27	—	69	53	13	25
female	11	18	51	100	156	68	57
female (with eggs)	6	23	—	—	—	—	—
female (with young)	—	—	9	—	—	—	—
female imm.	7	33	1	83	64	17	16
male (II?)	4	7	1	—	14	—	—
female (imm. ?)	—	10	4	—	12	—	—

b. Adult males in NYSM 6976 (stream survey collections)

	JUNE	JULY	AUG.	SEPT.
male I	5	22	35	3
male II	44	30	4	—

Adult males. The proportions of form I and form II males occurring through the seasons in New York (table 3) indicate the same life cycle which occurs in Illinois. In October, the last month of the year for which I have records, 87 percent of the males are form I; in fact, owing undoubtedly in part to chance in collecting, 98 percent of males are form I in September. Some of the individuals called form II, may really be large immatures, members of the group which reaches sexual maturity in its second summer. The condition in April is similar, the spring moult not having yet taken place. During May

and July, numbers of males are moulting; in May from form I to form II, and in July from form II back to form I again. My earliest record for a soft (freshly moulted) male I is June 21, 1951 (DWC 148). The other male I, recorded in June on the chart of seasonal data, was taken June 21, 1950 (DWC 36) and was very clean and apparently rather freshly moulted. The numbers of immature males decrease through the summer as these, becoming mature, are classed as males I.

Copulation. Dates on which I have observed copulation in New York are:

July 13, 1951 — 5 pairs

Aug. 25, 1950 — 3 pairs

Aug. 28, 1950 — 1 pair

Oct. 19, 1950 — 1 pair

In addition, I have two early records for the capture of females with sperm plugs, July 18, 1949 (DWC 3) and July 28, 1950 (DWC 47). Copulation must begin sometime in July in New York, possibly as soon as the males begin their return to form I. The frequency of finding sperm plugs in females increases until the late fall, when an adult female is only rarely found without one.

Unlike Van Deventer (p. 33) I have no observations of copulation in the spring, although I have watched for it in late March and in April, May and June. Van Deventer (p. 33) in summarizing the literature notes that the duration of the mating season varies widely in different localities. He states, "In more northern latitudes, such as Michigan and Wisconsin, it probably begins in July and August, and lasts until November, but does not occur again in the spring." Data on hand show this also to be true for New York State.

Egg laying. I have seen egg-laying in *O. p. propinquus* once. On April 23, 1950, in Fall Creek, Ithaca, N. Y., a female was noted lying on her back. The abdomen was flexed and the members of the tail fan extended. The chamber so formed was filled with a greyish mucous-like substance. Four eggs were contained in the mass.

Females with eggs. Females with eggs in my personal collection were taken in New York on the following dates:

April 13, 1951 — 1 specimen (DWC 75a)

April 23, 1950 — 5 specimens (DWC 21)

May 3, 1950 — 3 specimens (DWC 23)

May 6, 1951 — 3 specimens (DWC 83)

May 13, 1951 — 3 specimens (DWC 102)

May 19, 1951 — 5 specimens (DWC 109)

May 20, 1950 — 1 specimen (DWC 27)

May 20, 1951 — 4 specimens (DWC 135)

May 21, 1950 — 3 specimens (DWC 31)

May 25, 1951 — 1 specimen (DWC 129)

Collection NYSM 1939: 94 contains a female with eggs taken June 2.

The spawning season is apparently about a month later in New York State than it is in Illinois.

Hatching and early moults. A female with eggs was taken from Cascadilla Creek, Ithaca, N. Y., on May 25, 1951 and kept in a dish. Two days later the first of the eggs hatched, but most of the young died. I observed one first stage individual moulting to second stage at 5:30 p.m. on May 30, three days after the first eggs hatched. None of the young reached stage three before dying. The first and second stage individuals correspond closely in manner of attachment to the egg membranes and to the pleopods of the female, with the description of Andrews (1907) for *O. limosus*.

Females with young. I have but one date: June 21, 1950, when eight females with young were taken in one locality and one in another (DWC 33 and 36).

Size at sexual maturity. Although I have not measured all of my 414 males I, I have measured most of those appearing to be under 20 mm. carapace length. I believe that the size below which form I males could be considered exceedingly rare is about the same as the figure of 18 mm. given by Van Deventer (p. 31). The great majority of my males I are over 20 mm., and Van Deventer (p. 30) has reported similarly. My smallest male I is 16.2 mm. Van Deventer (p. 31) found one male I of only 12.6 mm. carapace length.

Minimal size is apparently the same for mature females. I have only eight specimens collected in late fall which are under 20 mm. The smallest female with eggs is 19.1 mm. (DWC 135); smallest female with young 16.5 mm. (DWC 36); smallest females with sperm plug, two specimens 16.4 mm. in carapace length (DWC 7 and 18).

Maximum size. Male I, 38.0 mm. carapace length (DWC 39b).

Female, 35.9 mm. carapace length (DWC 102).

There is an interesting phenomenon associated with maximum size which is best documented for, and perhaps occurs only in, males. Van Deventer (1937: 45-46) reasoning from measurements of *O. p. propinquus*, and Ortmann (1906: 471-472) reasoning from field observations of *O. obscurus*, both report an apparent dying-off of old males in the spring. Penn (1943) reports the same phenomenon for the southern *Procambarus clarki*. I, also, have some evidence that

this occurs. Both on April 23 and April 25, 1950, while observing *O. p. propinquus* activities in Fall Creek, Ithaca, N. Y., numbers of dead individuals were noticed lying on the stream bottom. Although some were disintegrating, others appeared to have died recently. None of these latter appeared to be mutilated. The proportions of the two sexes were not recorded. One male I, 25.3 mm. carapace length, was lying on its back still slightly active. Although it showed fairly vigorous activity when placed in a collecting bottle, it died four hours later. Superficially, at least, it appears perfectly normal (DWC 64).

Habitat. *O. p. propinquus* has ecological requirements similar to those of *C. robustus* for, as indicated in tables 4 and 13, each is the most common crayfish associate of the other. Like *C. robustus* it is rare in mountain stream habitats and in still water with a mud or silt bottom, but otherwise it is widespread in distribution in those stream systems which it occupies.

Crayfish associates are listed in table 4.

TABLE 4

Frequency of occurrence of *Orconectes p. propinquus* with other crayfish species in collections made in New York. Tabulated from D. W. Crocker collections 1-158, NYSM 6976 (stream survey collections) and NYSM 6977-7022 (collected in August 1952)

DRAINAGE	<i>C. b. bartoni</i>	<i>C. robustus</i>	<i>O. immunis</i>	<i>O. limosus</i>	<i>O. obscurus</i>	<i>O. virilis</i>
Genesee R.....	1	3	1			
Oswego R.....	5	28	4		2	
L. Erie-Niagara R.....		2	2			1
L. Champlain.....						1
Grass, St. Regis & Salmon R.....	3					
Oswegatchie & Black R.....	1	2				
Mohawk-Hudson R.....		2	4		1	
Susquehanna R. (East).....	1		1	3		
Chemung R.....	2		4			
Misc. L. Ontario tribs.....		12	13			

Orconectes obscurus

Ortmann (1906: 470-476) has made the most detailed life history observations on *O. obscurus*. Although his data are not as quantitative as are those of Van Deventer (1937) for *O. p. propinquus*, a comparison shows that the life histories of these two species differ only in details. The discussion here will be limited to a presentation of data for New York State, with the addition of data from Ortmann where mine are insufficient, or where his data differ.

TABLE 5

Seasonal data for *Orconectes obscurus* in New York

a. Tabulated from all specimens in D. W. Crocker collections 1-158 and in NYSM 6977-7022 (collected in August 1952)

	MAY	JUNE	JULY	AUG.
male I	46	..	4	72
male II	2	24	21	7
male imm.	23	2	6	66
female	3	19	17	56
female (with eggs)	7	..	..	..
female imm.	29	5	6	58
male (II?)	4	7	8	..
female (imm. ?)	3	5	12	..

b. Adult males in NYSM 6976 (stream survey collections)

	JUNE	JULY	AUG.
male I	4	18	17
male II	41	5	—

Adult males. The apparent sharp drop in males I and increase in males II which appears in table 5a in June is due to a limited range of collecting dates. The latest day of collecting in May is May 21, and the two June collections were made June 15. The four June form I males reported in table 5b were taken on the first three days of the month. Ortmann found that the first spring moult in the majority of individuals occurred in Pennsylvania in the first half of May. It apparently occurs later in New York State.

Copulation. The earliest date recorded by Ortmann for an observation of copulation is September 5. He records other dates for September, October and November.

Females with eggs. The following are my dates of capture of females with eggs.

May 6, 1951 — 1 specimen (DWC 87)

May 13, 1951 — 4 specimens (DWC 99)

May 19, 1951 — 1 specimen (DWC 111)

May 21, 1951 — 1 specimen (DWC 128)

Collection NYSM 1934: 588 contains a female with eggs taken June 20, from the Erie Barge Canal opposite the entrance of Nine-mile Creek, Mohawk drainage, Oneida County, N. Y.

Ortmann states that he found females with eggs very regularly from the beginning of April to the end of May. His extreme dates are April 6 and May 25.

Females with young. Ortmann gives three dates: May 30, June 5 and June 6.

Size at sexual maturity. My smallest male I measures 19.9 mm. carapace length (NYSM 7015). The smallest female with eggs measures 23.1 mm. carapace length (NYSM 1934: 588). Ortmann's smallest male I is 38 mm. total length and his smallest female with eggs measures 40 mm. total length.

Maximum size.

Male I — 44.0 mm. carapace length (NYSM 1937: 4808)

Male II — 37.3 mm. carapace length (NYSM 1934: 289)

Female — 47.8 mm. carapace length (NYSM 7022)

Ortmann records the maximum size as over 70 mm. total length.

TABLE 6

Frequency of occurrence of *Orconectes obscurus* with other crayfish species in collections made in New York. Tabulated from D. W. Crocker collections 1-158, NYSM 6976 (stream survey collections) and NYSM 6977-7022 (collected in August 1952)

DRAINAGE	<i>C. b. bartoni</i>	<i>C. robustus</i>	<i>O. immunis</i>	<i>O. p. propinquus</i>
Genesee R.....	1	4	1	
Oswego R.....		2		2
L. Erie-Niagara R.....	1	1		
Oswegatchie & Black R.....		1		
Mohawk-Hudson R.....	1	4	2	1
Allegheny R.....	7	17		

Habitat. No differences between the habitat preferences of this species and *O. p. propinquus* have been noted.

Crayfish associates. See table 6.

Orconectes limosus

The best, although a very incomplete, account of the life history of this species is given by Ortmann (1906). The remainder of the literature consists largely of brief mention of habitats. The exceptions are Andrews' studies of copulation (1895), egg-laying (1906a) and development of the young (1907). These last are all laboratory studies, but Ortmann (1906) compares his field information with Andrews' and finds few points of difference.

Ortmann concludes from his data that the life histories of *O. limosus* and *O. obscurus*, for which he has better data, agree in every particular, and that there are thus the following general events through the seasons:

1. Mating occurs in the fall.
2. Spawning takes place in the spring.
3. Males of the first form are rare in June and part of July in consequence of a spring moult to form II.
4. First form males appear in numbers in the last half of July and are ready to take part in the fall mating season.

TABLE 7

Seasonal data for *Orconectes limosus* in New York

a. Tabulated from all specimens in D. W. Crocker collections 1-158 and in NYSM 6977-7022 (collected in August 1952)

	FEB.	APRIL	MAY	JUNE	JULY	AUG.	SEPT.	OCT.
male I	4	..	5	1	..	25	1	37
male II	..	..	..	2	..	4	..	..
male imm.	..	..	1	..	..	31	4	18
female	4	1	3	1	1	24	1	35
female imm.	..	..	..	..	..	23	4	4
male (II?)	..	..	..	1	..	1	..	..
female (imm. ?)	..	..	3	..	..	2	..	..

b. Adult males in NYSM 6976 (stream survey collections)

	JUNE	JULY	AUGUST
male I	7	12	9
male II	9	20	5

Adult males. I have too few specimens taken in the critical months of May, June and July (table 7) to determine whether or not the season of moult is the same in Pennsylvania and New York.

Data on hand indicate the same situation as obtains for *O. p. propinquus*. Ortmann records two males I, with quite fresh shells taken on July 10, 1905.

Copulation. Ortmann gives the dates of field observations of copulation as September 4 and 10.

Females with eggs. Ortmann has one record, May 9.

Females with young. A single record from Ortmann, May 30.

Size at sexual maturity. My smallest male I is 23.5 mm. carapace length (NYSM 7000). This same collection has a 22.5 mm. female with sperm plug. Ortmann's minimal sizes for males I are 37 mm. (New Jersey) and 40 mm. (Pennsylvania) total length. Ortmann reports seeing copulation take place in specimens less than 45 mm. total length, and egg-bearing females as small as 40 mm. The data are insufficient but suggest that sexual maturity is attained in *O. limosus* at a slightly larger size than in *O. p. propinquus*.

Maximum size. My largest specimen is a female from Esopus Creek near Kingston, Hudson River drainage (DWC 20), which is 54 mm. in carapace length. Hagen (1870: 61) records a body length of 4.7 inches in very old specimens. Faxon (1914: 372, footnote) reports that the largest specimen of this species in MCZ is 124 mm. total length (MCZ 180).

Habitat. *O. limosus* has been usually described as a river crayfish, preferring slow water and a silt bottom. My personal collections are from only two localities in New York: Catatunk Creek at Candor and Catatunk Creek one mile east of Spencer, both in Tioga County. *O. limosus* appears to be restricted to the wider,

TABLE 8

Frequency of occurrence of *Orconectes limosus* with other crayfish species in collections made in New York. Tabulated from D. W. Crocker collections 1-153, NYSM 6976 (stream survey collections), and NYSM 6977-7022 (collected in August 1952)

DRAINAGE	<i>C. b. bartoni</i>	<i>C. robustus</i>	<i>O. immunis</i>	<i>O. p. propinquus</i>	<i>P. b. blandingi</i>
Susquehanna R. (East).....	5		1	3	
Lower Hudson R.....		1			3
Chemung R.....	3		1		

deeper segments of this stream where, consequently, the current is slower and the bottom composed largely of soft silt. The habitats of the 10 localities where this species was taken in August 1952 (table 17) are all characterized, at least in part, by silt.

Crayfish associates are given in table 8.

Orconectes immunis

Forney (1956) discusses raising this species for use as bait, but the only paper published on the life history of this species is the detailed study by Tack (1941). In Ithaca, N. Y., he found the following life history:

1. The eggs hatch about May 15.
2. The young reach 13-29 mm. carapace length by September and may become sexually mature at this time, but most are not sexually mature until late in their second summer.
3. From mid-November until late March or April no moulting occurs.
4. Copulation occurs from mid-July to early October, mostly among yearling individuals.
5. The eggs are laid during late October or early November and are held on the pleopods through the winter.
6. The normal life span of *O. immunis* in the Ithaca region is two years.

TABLE 9

Seasonal data for *Orconectes immunis* in New York

a. Tabulated from all specimens in D. W. Crocker collections 1-158 and in NYSM 6977-7022 (collected in August 1952)

	APRIL	MAY	JUNE	JULY	AUG.
male I	61	3	2	5	9
male II	..	9	3	1	3
male imm.	118	1	2	12	2
female	5	6	4	7	7
female (with eggs)	78	1	..	..	..
female (with young)	..	1	..	..	..
female imm.	142	..	3	17	1
male (II?)	..	3	..	2	1
female (imm. ?)	..	3	..	3	..

b. Adult males in NYSM 6976 (stream survey collections)

	JUNE	JULY	AUG.	SEPT.
male I	5	2	3	7
male II	10	9	2	1

Adult males. The large numbers of immatures appearing in April (table 9) make it plain that the majority of young hatched the previous summer have wintered over as immatures. The criterion used in the present study for separating adults from immature individuals is 23 mm. carapace length.

Tack found the first spring moult of adult males to occur about the middle of April. The second he reports as less pronounced, but it begins in about the last week of June.

Females with eggs. Dates of collection are April 13, 1951 (DWC 75); April 28, 1950 (DWC 39); May 20, 1950 (DWC 27). Tack's earliest fall dates are October 18, 1937, October 23, 1935 and October 24, 1936.

Females with young. The record in table 9 is for May 20, 1950 (DWC 27). Tack gives mid-May as the time of hatching.

Size at sexual maturity. My smallest male I is 23.2 mm. carapace length (DWC 39b). The smallest female with eggs is 23.0 mm. (DWC 39b). Tack reports but one smaller female with eggs than this: 22 mm. He gives no minimal size for mature males.

TABLE 10

Frequency of occurrence of *Orconectes immunis* with other crayfish species in collections made in New York. Tabulated from D. W. Crocker collections 1-158, NYSM 6976 (stream survey collections) and NYSM 6977-7022 (collected in August 1952)

DRAINAGE	<i>C. b. bartoni</i>	<i>C. robustus</i>	<i>O. limosus</i>	<i>O. obscurus</i>	<i>O. p. propinquus</i>	<i>O. virilis</i>
Genesee R.....				1	1	
Oswego R.....		2			4	
L. Erie-Niagara R.....					2	1
Grass, St. Regis & Salmon R.....						1
Mohawk-Hudson R.....	1	2		2	4	
Susquehanna R. (East).....	1		1		1	
Chemung R.....	2		1		4	
Misc. L. Ontario tribs.....		1			13	

Maximum size. The largest specimen on record or seen by me is in NYSM 1939: 1650. It is a female with a carapace length of 48.8 mm., from Glenwood Lake, Ontario County, N. Y.

Food. Analysis of stomach contents, direct observation and preferences shown in feeding tests show (from Tack) that *O. immunis* is largely a vegetarian. Tack does not separate his data for size classes of crayfish.

Crayfish associates are listed in table 10.

Orconectes virilis

No account of the life history of *O. virilis* has been published and what little is known is widely scattered in the literature as brief notes, most of which relate to habitat. Steele (1902) gives some information on the life history in Missouri of a species which she considers to be *O. virilis*, but Creaser (1933b: 3) says that *O. virilis* does not occur in Missouri and that she must have had *O. nais*.

Seasonal data. The meager data available for New York are summarized in table 11.

TABLE 11

Seasonal data for *Orconectes virilis* in New York. Tabulated from all specimens in D. W. Crocker collections 1-158, in NYSM 6976 (stream survey collections), and in NYSM 6977-7022 (collected in August 1952)

	MAY	JUNE	JULY	AUG.
male I	1	..	..	7
male II	..	8	2	4
male imm.	..	..	..	23
female	2	..	..	7
female imm.	1	..	..	24
male (II?)	2	..	..	..
female (imm.?)	..	3	..	..

Copulation. Fasten (1914: 603, table 1) reports two periods of copulation in Wisconsin: April-May and September-October. His data are derived from the cytology of the testis and condition of vasa deferentia.

Egg laying. Creaser (1931: 263) reports that in Michigan the eggs are laid before the last of April. Pearse (1910: 18) gives a record of a female with eggs on April 14 in the same State.

Maximum size. The largest male I seen by Pearse (1910: 17) measured 55 mm. carapace length. Creaser (1932: 326) speaking of *O. virilis* in Wisconsin says, "This species is the largest in the State and frequently attains a size of over eight inches."

Habitat. Pearse (1910: 18) says that this species is found in the lakes and larger streams in Michigan. Creaser (1931: 263) for the same State says it prefers streams with a bottom of stones and is found "... in even the coldest streams where the fish fauna is limited to *Cottus*, the miller's thumb, and *Salvelinus*, the brook trout."

My own two collections of *O. virilis* (DWC 119 and 121) are from the Little Chazy River, near its mouth, Clinton County, and from the Salmon River at Fort Covington, Franklin County. Both habitats are in slow-moving turbid water where the bottom is mud and silt with numerous patches of aquatic plants.

The stream survey collections, of which there are five of this species, carry no habitat data, but I was able to take *O. virilis* in three localities during the August 1952 collecting. These are as follows:

1. NYSM 6978, stream (probably Kayaderosseras Creek) at bridge on rt. U. S. 9, 2.3 miles south of city limits of Saratoga Springs. Scattered boulders, dense silt, slow current and slightly dark water. About 30 feet wide and up to 3 feet deep.
2. NYSM 6985, Lake George outlet in town of Ticonderoga. Bottom of silt, scattered boulders and considerable rubbish.
3. NYSM 7017, east shore and at park at south end of Grand Island, Niagara River. Because of misidentification of these (all immature) specimens in the field, I have no specific habitat data for them; the Grand Island material from several habitats was lumped together as one collection.

Crayfish associates. Three collections contain *O. virilis* with another species: with *O. immunis* in the Niagara and Salmon Rivers and with *O. p. propinquus* in the Niagara River and Lake George outlet.

Cambarus robustus

Discussion. The literature contains practically no information regarding the life history of *C. robustus*. This fact was recognized early in the present study and because *C. robustus* is common in the Ithaca region, the attempt was made to study its life history, particularly by marking methods.

In an intensive study of *O. p. propinquus* in Illinois, Van Deventer (1937) collected and measured in the field large numbers of specimens and then returned them to the stream. He was able to accumulate data which showed the growth rate of this species at all stages of its life. He could also determine length of life, age at sexual maturity and other pertinent facts.

However, in *C. robustus* there is apparently no restricted, at least no single period, during which the eggs are laid and hatched as there is in *O. p. propinquus*. It follows therefore, that, unlike *O. p. propinquus*, graphic plots of frequency distribution of size of *C. robustus*, measured at regular intervals of time, will not show a given year-class as distinct from the remainder of the population. Because of this, *C. robustus* is particularly well suited as a subject of growth study by marking individuals so that they may be subsequently recognized when collected from their natural habitat.

Here, one is led to ask: How can an animal which moults be marked so as to still be recognizable as a marked animal after moulting? I have tried three methods, all apparently unsuccessful. These have been reported upon elsewhere (Crocker 1952), but briefly they are the following: (1) Punching holes in various of the five members of the tail fan, a method used on lobsters with success by Wilder (1948); (2) insertion of bits of metal (tantalum wire, silver sheet, silver wire) into the haemocoel, to be recognized subsequently by means of X-ray; (3) a method used successfully on spiny lobsters by Creaser and Travers (1950), which involves inserting barbed plastic tabs between terga into the abdominal musculature.

TABLE 12

Seasonal data for *Cambarus robustus* in New York

a. Tabulated from all specimens in D. W. Crocker collections 1-158 and in NYSM 6977-7022 (collected in August 1952)

Numbers in parentheses refer to additional adult males, recorded in the field as to form and liberated as marked animals.

	APRIL	MAY	JUNE	JULY	AUG.	SEPT.	OCT.	NOV.
male I	18	71	8	6	6(10)	9(13)	24(20)	..
male II	8	36	13	11	14(21)	14(3)	24(13)	2
male imm.	8	59	13	8	11	3	12	..
female	42	148	10	12	17*	14	63	2
female (with eggs)	..	..	..	2	..	..	..	..
female (with young)	4	..	..	..	1	..	..	..
female imm.	18	77	11	8	15	2	7	1
male (II?)	..	16	1	..	1	1	9	..
female (imm. ?)	..	15	5	..	4	..	..	..

b. Adult males in NYSM 6976 (stream survey collections)

	JUNE	JULY	AUGUST
male I	25	8	3
male II	12	12	5

Methods one and three failed apparently because of the small size of crayfishes as compared with lobsters and spiny lobsters. Method two may still give results with the use of metal pellets, instead of wire and sheet. These latter either punctured vital organs or worked to the surface much as does a splinter in a finger.

Marking methods attempted for this species having failed up to the present to produce results, life history information must be summarized from field and laboratory observations and data from collections.

Adult males. It is apparent from table 12 that the restriction of form II males to the summer is not the case for *C. robustus* as it is for *O. p. propinquus*. This fact has been pointed out previously by Ortmann (1906: 488). In Pennsylvania, Ortmann found males I in the months of May, July, August, September, October and November, and males II in the months of May through October. I have a field record for a male moulting from form I to form II on September 21, 1950, and records of numerous soft males of both forms in September.

Thus, apparently at all times of the year there are males capable of copulation. Months unsampled are December through March. The data show relatively fewer males I in June, July and August and relatively fewer males II in April, but it is not certain how true a picture this may be.

Copulation. I have but two dates of copulation for this species, occurring under completely natural conditions in the field: October 8, 1949 and October 19, 1950. Two additional dates are May 23 and May 30, 1951, but these specimens were crowded in with a number of others of the same species in a lamprey trap.

One of the pairs from the lamprey trap was placed in boiling water and fixed in position. The positions of male and female correspond to the descriptions of Andrews (1895) for *O. limosus*. The right fifth pereopod was used by the male to depress his stylets. Particularly well shown by this pair is the function of the hooks on the ischia of the male's third pereopods. These, one on each side, were hooked over a prominent projection on the coxae of the female's fourth pereopods to such an extent that the soft membranes dorsad of the projections were deeply impressed.

Although sperm plugs are common in the fall in all the New York State species of *Orconectes* (except *O. virilis* for which data are lacking), I have yet to find a sperm plug in *C. robustus* or in *C. b. bartoni*. All of the adult female *C. robustus* in my personal collection (295 specimens) have been examined for it.

Egg laying. I have seen two females of this species lay eggs, both in captivity. The dates are July 2, 1950, and April 7, 1951. The process is as reported by Andrews (1906a) for *O. limosus*. The female lies on her back and secretes a mass of mucous-like material into the chamber formed by the flexed abdomen and extended members of the tail fan. It is into this mass that the nearly black eggs are laid. The mucous disappears in about a day and a half. Each of these females had 30-40 eggs. Carapace lengths were 38.4 and 35.0 mm.

The dates for capture of females with eggs in the field are July 13 (DWC 154) and July 23 (DWC 158), 1951; carapace lengths 35.0 and 31.2 mm. Ortmann (1906: 488) took a female with eggs in Crawford County, Pennsylvania on July 11, 1905; total length 84 mm.; number of eggs 228.

Hatching and early moults. The dates for capture of females with young in the field are April 28 and August 13, 1950, and April 13, 1951. I have a measurement only for the August specimen — 39.2 mm. (DWC 72, specimen 23).

The eggs laid by the female in captivity on April 7, 1951, were first noticed to be hatching on May 24, an interval of over six weeks. The water temperature in the large aquarium in which the animal was kept varied not over two degrees above or below 60 degrees Fahrenheit. On May 25, 13 young were counted and, because they were crawling rather actively over the pleopods of the female, yet were without the five distinct members of the tail fan, they were probably stage two of Andrews (1907: 50). On May 29, only two young remained, the rest were not in evidence, dead or alive, and it is supposed that the mother ate them. Of the two remaining, one was third stage and was preserved. In a slightly shrunken condition it measures 4.7 mm. carapace length. The other, a stage two individual, was kept alive and sometimes between 11 p.m. on May 29 and 10 a.m. on May 30, moulted into third stage. Careful watch was kept on this single individual to detect another moult. Active feeding was first noticed on June 4, when the intestine became visible as a dark line due to its contained food material. The only food available was a rich coating of protozoa-laden algae in the bottom of the dish. On June 28 the animal measured 5.4 mm. carapace length. No cast exoskeleton was found and the animal died on August 4, 1951. It measures 5.6 mm. carapace length.

Immatures under 20 mm. carapace length in my collections or in NYSM collections were taken in May through October.

Moulting. The increment of growth of individuals living under natural conditions has been ascertained in two cases. On September

21, 1950, a male moulting from form I to form II was captured (DWC 65). Its change in carapace length was from 34.8 to 39.3 mm., an increment of 4.5 mm. A female, taken on May 5, 1951, and kept in an aquarium, moulted on May 24, only 19 days later; change in carapace length from 35.1 to 37.6 mm., an increment of 2.5 mm.

A moult by the majority of the adult population in September is indicated by field observation. On September 18, 1950, in Fall Creek at Forest Home, Ithaca, Tompkins County, N. Y., about half of many adult *C. robustus* were soft, yet in this same area on September 30, only one soft animal was seen. Similarly, in Taughannock Creek at Perry City, boundary of Tompkins and Schuyler Counties, N. Y., about 20 *C. robustus* were seen on September 21, 1950. Only two hard individuals were present out of 10-15 large specimens. Both males and females were seen soft, also both males I and males II. Two females were seen half moulted. Yet on October 7, not one soft animal could be found.

TABLE 13

Frequency of occurrence of *Cambarus robustus* with other crayfish species in collections made in New York. Tabulated from D. W. Crocker collections 1-158, NYSM 6976 (stream survey collections), and NYSM 6977-7022 (collected in August 1952)

DRAINAGE	<i>C. b. bartoni</i>	<i>O. immutis</i>	<i>O. limosus</i>	<i>O. obscurus</i>	<i>O. p. propinquus</i>
Genesee R.....	3			4	3
Oswego R.....	10	2		2	28
L. Erie-Niagara R.....	1			1	2
Oswegatchie & Black R.....	4			1	2
Upper Hudson R.....	1				
Raquette R.....	2				
Mohawk-Hudson R.....	1	2		4	2
Lower Hudson R.....			1		
Allegheny R.....	5			17	
Misc. L. Ontario tribs.....	2	1			12

Size at sexual maturity. Of the form I males which I have seen, the smallest measures 31.7 mm. carapace length. This specimen is from Herkimer County, N. Y., at the outlet of Little Moose Lake (DWC 143). Because of the large number of males I (215) which have come under my observation, and because the smallest in all collections have been measured, this value of minimal size is believed to be close to the actual limit. A form I male in NYSM 7021 is so much smaller than this (26.4 mm.) that I consider it abnormal.

The smallest female with eggs (DWC 158) measures 31.2 mm. carapace length and is the smallest normal sexually mature specimen of this species which I have seen or which has been reported.

Maximum size. Male I, 52.4 mm. carapace length (NYSM 1929: 1152).

Male II, 51.8 mm. carapace length (DWC 135).

Female, 55.4 mm. carapace length (DWC 32).

Food. Notes on the food of this species are given by Creaser (1934: 160) who found that in 11 specimens ranging from 42 to 76 mm. total length, the smaller fed largely on insect larvae or naiads, the larger on aquatic plants. The largest three stomachs contained only aquatic plant remains.

Habitat. The ecological requirements for this species are not as restricted as are those of *C. b. bartoni*. It is rarely found in cold mountain streams, the preferred home of *C. b. bartoni*, and it is equally rare in standing water where the bottom is of mud and silt. Otherwise, it has been taken from both ponds and streams of extensive variety. Burrowing habits have not been observed in New York State except for a rather casual digging out of shelters under boulders in streams.

Crayfish associates are listed in table 13.

Cambarus b. bartoni

Other than Williamson's note (1899: 47) of finding a female with young, Ortmann (1906: 486-488), working in Pennsylvania, has contributed the only information on the life history of this subspecies. Owing to its relatively infrequent occurrence near Ithaca, N. Y., I can only present some information which tends to confirm the findings of Ortmann.

Adult males. Ortmann (1906: 487) reports first form males in the months of March through December. He did no collecting in January and February. He gives no quantitative data on the relative frequency of males I and males II. My own data (table 14) show

TABLE 14

Seasonal data for *Cambarus b. bartoni* in New York

a. Tabulated from all specimens in D. W. Crocker collections 1-158 and in NYSM 6977-7022 (collected in August 1952)

	APRIL	MAY	JUNE	JULY	AUG.	SEPT.	OCT.
male I	3	10	1	3	18	4	..
male II	4	11	9	3	13	4	..
male imm.	..	7	2	13	26	..	..
female	9	35	11	3	23	1	1
female (with young)	2	..	..	..	1	..	..
female imm.	..	11	2	8	18	..	..
male (II?)	..	6	1	..	16	1	..
female (imm. ?)	2	..	..	..	13	1	..

b. Adult males in NYSM 6976 (stream survey collections)

	JUNE	JULY	AUG.
male I	4	2	7
male II	25	8	6

that, as in *C. robustus*, there are apparently fewer males I in June and July, but there are fewer specimens of *C. b. bartoni* on which an opinion can be based.

With these small numbers also, a relative infrequency of males II is not apparent. Ortmann (1906: 487) found males II in all months except January and February, in which months he did no collecting.

Males of this subspecies, capable of copulation, are present during at least 10 months of the year.

Copulation. I have not observed copulation in this subspecies. Ortmann (1906: 486) gives only two dates: May 27, 1904, and October 6, 1905.

Females with eggs. Ortmann (1906: 486) found females with eggs in July and August. The number of eggs was between 7 and 133, the smallest number on the smallest individual.

Females with young. My three records are April 1940 (DWC 74), April 22, 1951 (DWC 77) and August 29, 1952 (NYSM 7014). Ortmann (1906: 486-487) reports females with young taken in the months of February, March, August, September and November. The February record is for New Jersey. I have taken immature specimens under 15 mm. carapace length in May, June, July and August.

Size at sexual maturity. The smallest male I which I have seen is 18.5 mm. carapace length (NYSM 6989). The next smallest is 21.4 mm. (DWC 120) and I have a few others close to this. The

smallest male I of *C. b. bartoni* reported by Ortmann (1906: 487) is 49 mm., total length.

The only female with young for which I have a measurement is 28.8 mm. carapace length (DWC 74). Ortmann's smallest female with either eggs or young is 48 mm., total length, which is approximately 7 mm. smaller than my smallest *C. robustus* (a female).

Maximum size. Male I, 36.7 mm., carapace length (DWC 118).

Male II, 36.3 mm., carapace length (DWC 108).

Female, 38.8 mm., carapace length (DWC 108).

Size comparison of *C. b. bartoni* and *C. robustus*. The above data indicate that *C. b. bartoni* is a distinctly smaller species; from 7 to 13 mm. smaller in minimal size at sexual maturity and approximately 16 mm. smaller in maximum size.

TABLE 15

Frequency of occurrence of *Cambarus b. bartoni* with other crayfish species in collections made in New York. Tabulated from D. W. Crocker collections 1-158, NYSM 6976 (stream survey collections) and NYSM 6977-7022 (collected in August 1952)

DRAINAGE	<i>C. robustus</i>	<i>O. immutis</i>	<i>O. limosus</i>	<i>O. obscurus</i>	<i>O. p. propinquus</i>
Genesee R.....	3			1	1
Oswego R.....	10				5
L. Erie-Niagara R.....	1			1	
Grass, St. Regis & Salmon R.....					3
Oswegatchie & Black R.....	4				1
Upper Hudson R.....	1				
Raquette R.....	2				
Mohawk-Hudson R.....	1	1		1	
Susquehanna R. (East).....		1	5		1
Allegheny R.....	5			7	
Chemung R.....		2	3		2
Misc. L. Ontario tribs.....	2				

Smaller size at sexual maturity may be due either to reaching such maturity at an earlier age in *C. b. bartoni* or to reaching maturity at the same age, but at a smaller size due to a slower growth rate. Both factors may, of course, be in operation. Smaller maximum size may be produced by a slower growth rate, a shorter life, or both.

Habitat. *C. b. bartoni* is typically a mountain stream form, occurring most commonly in cool, fast flowing, well-oxygenated water where there is a bottom of boulders and rubble. If it is found in larger streams, then it is almost invariably at the point of entrance of cold spring water. Burrowing has not been observed in New York State.

Crayfish associates of this species are listed in table 15.

Procambarus b. blandingi

There are six members of the Blandingi subgroup; namely, three subspecies of *P. blandingi* and in addition *P. hayi*, *P. lecontei* and *P. bivittatus* (Hobbs 1942b: 94). Practically nothing is known about the life histories of any of these. Hobbs (1942b: 95) reports 37 males I of *P. b. acutus* taken in Florida in May. In the same publication (p. 98) he also states that of 133 specimens of *P. bivittatus* taken in Florida in the months of April, May and October, first form males were taken in May. Penn (1943) has worked out the life history of a member of the same genus, *P. clarki*, but this species is in a different subgroup of the genus and the locality of study is Louisiana. His data may or may not apply to the present species. Penn (1943: 14) places sexual maturity of both males and females of *P. clarki* at 31-32 mm. carapace length.

Seasonal data. The three stream survey collections containing *P. b. blandingi* were all taken in July (NYSM 1936: 2960, 3576 and 3616). They contain two males I, one male II (soft), and two females (one soft). Collection USNM 74747, taken in August from the Bronx River, New York City, contains a male I and a female of *P. b. blandingi*. The female has a sperm plug. Collecting in the Bronx River on August 25, 1952 produced one male I, two males II, six females and one female immature (NYSM 6999).

Habitat. Of its preferred habitats, only slightly more is known. Abbott (1873: 80) describes it as a plant-loving species in New Jersey, frequenting clear running streams where it is to be found resting on aquatic plants, usually near the water surface. Later (Abbott 1886: 167), he decides that this species is not so restricted in habitat. P. R. Uhler, according to Faxon (1885b: 23), reports

P. b. blandingi from salt marshes covered twice daily by the tides in company with *Cambarus uhleri*, and characterizes this species as belonging to the lowlands at the mouth of sluggish rivers or near the ocean in muddy and grassy ditches and drains. Uhler also found it in a ditch near Ocean City, Worcester County, Md. in holes six to nine inches deep, and at Goldsborough, N. C. in drains and branches running through cotton fields.

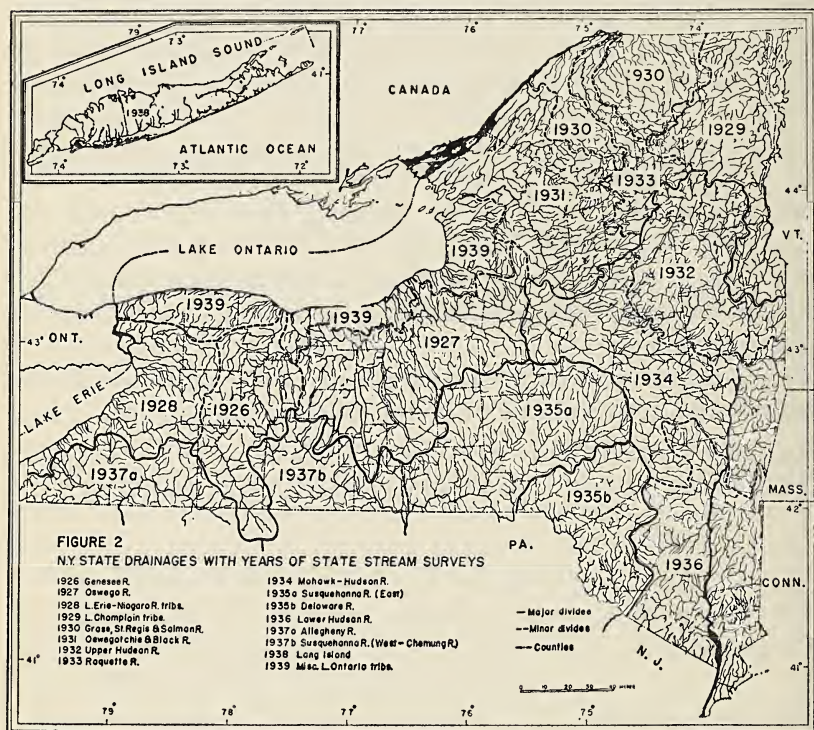
The only New York State locality for this species, Bronx River, has been studied by F. R. Nevin (1937: 228-230) with reference to the quantities of food organisms of fish. He reports that in the vicinity of White Plains, crayfish (unidentified) and mollusks occur in greatest quantity (weight per square foot) and that it is also here that sewage pollution is greatest. He also states that, except for the northern part, the stream has few stony areas and that when stones are present they are set in sand. Finally, he mentions that pollution other than sewage is prevalent within the limits of New York City and that the stream margins here are mud, mingled with a mass of decaying vegetation.

My August 1952 collection from Bronx River at White Plains North Station (NYSM 6999) was made in knee-deep muck.

Crayfish associates. Three NYSM collections from the lower Hudson River contain *O. limosus* in addition to *P. b. blandingi*.

DISTRIBUTION

Figure 2, following, should provide a ready reference to the names of the drainage systems in New York State and to the years during which stream surveys were made.

*Procambarus b. blandingi*

(FIGURE 3)

Procambarus blandingi consists of three subspecies: *P. b. blandingi* (Harlan), *P. b. acutus* (Girard) and *P. b. cuevachicae* (Hobbs). *P. b. blandingi* is restricted, in so far as is known, to the Atlantic coastal plain from the Bronx River, New York to at least as far south as South Carolina. *P. b. acutus* is distributed in the Mississippi River system. *P. b. cuevachicae* is described from La Cueva Chica, a limestone cave in the State of San Luis Potosi, Mexico.

The questionable status of the members of the *blandingi* complex has already been mentioned and it is inadvisable to attempt dis-

tributional theorizing until larger series become available and are studied.

The pattern of distribution in a very general sense has been investigated by Ortmann (1905a: 103-106). He places the origin of what is now the genus *Procambarus* in Mexico, and of the Blandingi section in the southern States, chiefly Alabama and Georgia. Ortmann (p. 105) states of the Blandingi group that it "... invaded (*C. fallax*) northern Florida and spread out northeastwardly along the Atlantic coastal plain (*C. blandingi-typicus*), and also it migrated westward and northward, up the Mississippi Valley (*C. hayi* and *blandingi acutus*)."

P. b. blandingi has reached New York by following the retreating ice northward along the coastal plain, but has not left its lowland habitat.

The only acceptable published report of this subspecies in New York (Faxon 1885b: 19) gives no specific locality.

Mayer (1911: 88) says, "In the neighborhood of New York we find three common species." He lists *P. b. blandingi* as one of these, but no specific localities are given, and the description of habits appears to have been taken from Abbott (1873: 80).



Orconectes virilis

(FIGURE 3)

Orconectes virilis ranges through a number of states in streams tributary to the Mississippi River. Northward it extends into Saskatchewan and Ontario. In Ontario, Huntsman (1915: 161) reports it as "... quite abundant in Georgian Bay but not [as abundant] in Lake Ontario." It is pointed out under the discussion of distribution of *C. robustus* that its limits in Canada are unknown. *O. virilis* is absent from Pennsylvania (Ortmann 1906). Turner (1926: 176-178, map 1 on p. 171) gives records for southwestern Ohio, but Rhoades (1944a: 96) has not been able to substantiate these records in the field. He states that *O. virilis* will undoubtedly be found in the extreme northeastern counties of the State, which Turner also suggested. Pearse (1910: 18) describes it as the most abundant species in the northern part of Michigan.

In New York, its distribution as now known suggests two entrances from the west, for there are no known populations on the coastal plain of Lake Ontario between the five northeastern localities and the Lake Erie-Niagara River records. The separating area has been well sampled (see figures 4, 5 and 6) and the habitat is relatively uniform and apparently not unlike that in the localities where *O. virilis* has been taken in New York.

The Lake Erie-Niagara River localities may represent an entrance as early as the time of Lake Maumee. The northeastern records are accounted for by an entrance from the west into what are now western St. Lawrence waters, through the Kirkfield or Ottawa outlets (Leverett and Taylor 1915: 410 and plate 21). These outlets existed in Lake Algonquin time before the invasion of the Champlain Sea. Furthermore, during this time the Hudson and Champlain waters were united and the localities in the Hudson River drainage in Saratoga Springs and in Westchester County may perhaps be explained as relict populations. However, one cannot ignore Faxon's (1885b: 98) report that *O. virilis* and *O. immunis* are two of the western species of crayfish most esteemed as food and that they are sometimes sent to the New York market from Milwaukee and other western cities.

Hagen (1870: 65) gives the oldest record for this species in New York. Faxon (1885b: 98) has cast doubt on Hagen's record, a dry specimen from Lake George, pointing out that the labels of dry specimens are easily transferred. However, I have substantiated Hagen's record by taking *O. virilis* at Ticonderoga on August 20,

1952 (NYSM 6985). The only other previous New York record is for the Raquette River watershed (Creaser 1934).

Orconectes immunis

(FIGURE 4)

The distribution of *O. immunis* is generally widespread and like that of its close relative *O. virilis*. That the two close forms can occupy such a similar territory is probably due to their different habitat requirements. In the west at least, *O. virilis* appears to be typically a stream form and *O. immunis* an inhabitant of ponds and ditches.

The literature contains nine New York locality records for this species:

Faxon (1898: 654). MCZ 4330; Small stream tributary to Oneida Lake.

Ortmann (1906: 467). Rensselaer Lake, Rensselaer County.

Faxon (1914: 378-379). USNM 22,417; pond near mouth of Cattaugus Creek, Chautauqua County.

USNM 22,408; Silver Creek, Chautauqua County.

USNM 22,418; Fish Creek, Buffalo, Erie County



USNM 22,409; Stony Island at the eastern end of Lake Ontario, Jefferson County.

Creaser (1934). Raquette River.

Nevin and Townes (1935). Mohawk-Hudson drainage.

Tack (1941). Ithaca, Tompkins County.

Thus three records are known (USNM 22, 417; 22,408; 22,418) in the Erie-Niagara drainage in addition to the two shown in figure 4. Its apparent scarcity in this drainage may be due to poor coverage.

The distribution of *O. immunis* in New York can be accounted for by an entrance from the west in Lake Lundy time or perhaps not until Lake Iroquois (Fairchild 1912: plate 17).

In view of the absence of *O. immunis* from the Allegheny River, I attribute the single locality shown in figure 4 in the upper Genesee River above the falls at Portageville, to introduction by man.

An isolated locality for this species in the eastern Susquehanna (Oakes Creek, NYSM 1935: 702) shown in figure 4, might be accounted for by a connection between glacial Lake Herkimer in the Mohawk Valley and the Susquehanna through the Otsego Valley (Fairchild 1912: 39, plate 1). If one assumes that *O. immunis* reached the isolated locality through this Lake Herkimer outlet, then one is still faced with a problem: Why did it not achieve wider distribution? Perhaps competition with the already established *O. limosus* prevented the spread of *O. immunis*, but there is no information bearing on this from other areas because the two species do not normally come in contact. In fact, present knowledge of the distributions of these two species indicates that only in New York and the northern New England States (from which latter there is almost no information) could one expect to find them together. Collecting in the eastern Susquehanna has not been intensive, but coverage is fair (figures 5 and 7) and I do not think the apparent general absence of this species from the region can be attributed to poor sampling.

Ortmann (1906: 466-467) was unable to find *O. immunis* in Pennsylvania, and it is my opinion that the Susquehanna River drainage records in New York near the confluence of the Chemung and Susquehanna proper are also best explained by recent entry. Dr. Robert Ross, now of Virginia Polytechnic Institute, has told me that in the Cayuta Lake area in times of flood, one can stand on the Susquehanna-Oswego River divide knee deep in water. This offers a satisfactory explanation for the entrance both of *O. immunis* and *O. p. propinquus* (figure 5) into the Susquehanna River system.

O. p. propinquus and *O. obscurus*

(FIGURE 5)

Ortmann (1906: 434-447) has discussed the distribution of these two species and a third form, *O. p. sanborni*, in detail. The distributions of *O. p. propinquus* and *O. obscurus* in New York present no contradictions.

Ortmann places the origin of these three crayfishes, each in one of three tributaries of the preglacial Old Erigan River which ran in a northeasterly direction. With the advance of the ice, three populations of the original stock were isolated and underwent differentiation — *O. p. propinquus*, most westerly in the Old Miami or Cincinnati River; *O. p. sanborni* in the center in the Old Kanawha; *O. obscurus* in the east in the Old Monongahela. The ice, melting and receding, formed lakes of the eastern and central areas which eventually drained southwest and united all three localities. The western area became the lower Ohio River, the central became the middle Ohio and the eastern became the upper Ohio, which also united with the Allegheny River.

However, the western region opened up first and *O. p. propinquus* was enabled to make its way to Lake Maumee, thus accounting for the distribution in Indiana, Illinois, Iowa and Wisconsin. Data now made available for New York indicate that *O. p. propinquus* followed eastward the shores of Lake Maumee and its subsequent stages, Lake Lundy and Lake Iroquois, and was also able to enter the St. Lawrence when it was formed.

One is tempted to account for the presence of *O. obscurus* in the Genesee River by entry through the Olean outlet, a connection between the Genesee and Allegheny (stage 2 of Fairchild 1912: plate 10). However, it is a question whether or not *O. obscurus* entered the Susquehanna River system during a later connection between it and the Genesee (Fairchild, 1912: plate 11). It is possible, of course, that *O. obscurus* entered the Genesee before the Genesee-Susquehanna connection appeared and that it did not utilize this subsequent connection.

My two records of *O. obscurus* in the Susquehanna system are from isolated ponds (NYSM 1937: 2049 and 4517). The coverage of the area is poor and further collecting is needed before it can be said whether they more probably represent natural populations or introductions by man.

However, should the Susquehanna records be best explained as introductions by man, there is another means by which *O. obscurus* may have made the passage across the Allegheny-Genesee divide

after the closure of the Genesee-Susquehanna connection. This would therefore make it unnecessary to assume that, although the connection was available to *O. obscurus*, it was not utilized. Ortmann (1906: 443), unable to find *O. obscurus* in the Susquehanna drainage in Pennsylvania, accounts for its presence in the Genesee by known instances of the capture of morainic lakes, originally draining into the Allegheny system, by Genesee River tributaries (Fairchild, 1896: 447). These captures may have occurred after the closure of the Genesee-Susquehanna connection.

The populations of *O. obscurus* which occur in a restricted area of the Lake Erie drainage in Ohio and Pennsylvania are accounted for by cases of stream capture which are known in this area or by migration through canals (Ortmann, 1906: 441-442). This species has apparently been restricted from migration down the Ohio River by the presence there of its close relative *O. p. sanborni*.

O. obscurus may have moved eastward as early as Lake Whittlesey time, utilizing lakes at the edge of the ice, and may have entered the Mohawk River drainage as late as very early Lake Iroquois time, when a connection at what is now Rome would have permitted this (Fairchild, 1912: plate 16). Collection USNM 74,708 is an additional record for this species in the Mohawk River. At this same time there was also a union of the Mohawk and Black River drainages which would account for the records of *O. obscurus* in the Black River. However, its present distribution in the Mohawk and Black Rivers may also be accounted for by a following of the Erie barge canal eastward and an entrance into the Black River through the Trenton feeder. A single specimen is the basis for the record of *O. obscurus* at Long Lake in the town of Long Lake in the headwaters of the Raquette River drainage. Verbal testimony from bait dealers in this area indicates that large numbers of crayfishes are brought into the Adirondacks from numerous regions, particularly from the barge canal in the vicinity of Utica.

The species-locality of an old (1893) collection of *O. obscurus* in the United States National Museum (USNM 44,751), labeled as coming from Cattaraugus Creek in the Lake Erie drainage of New York (reported by Faxon, 1914: 374), has been substantiated by my collecting in 1952 (NYSM 7015). A connection between the Allegheny River and a glacial lake in the Cattaraugus Valley (Fairchild, 1912: plate 11) could account for the entrance of *O. obscurus* into this area.

Collection USNM 74,712 consists of five male *O. obscurus*, collected by H. K. Townes, August 31, 1934, in Kinderhook Creek at Kinder-

hook (Columbia County). I am unable to account for this species-locality. It is 100 miles from the upper Mohawk where the main body of the Hudson drainage members of this species is located. Subsequent collecting in the Kinderhook-Valatie area (DWC 132) has produced only *O. limosus*.

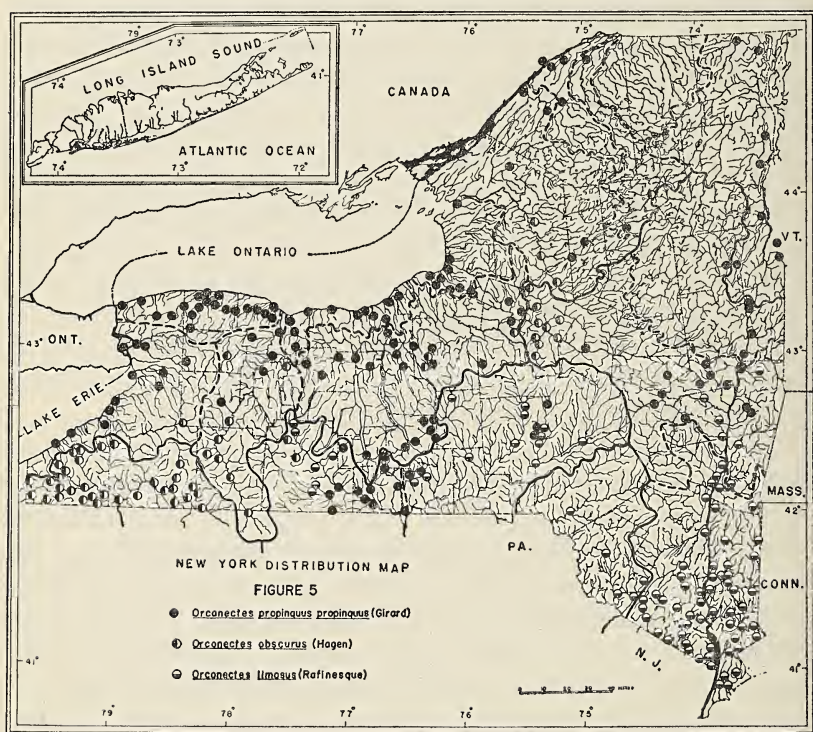
O. p. propinquus must not have entered the northern drainages of New York State before Lake Hall time, for previous to this time there were connections between the Genesee and Susquehanna and also direct drainages through what are now the Finger Lakes. I can not believe that the records for *O. p. propinquus* in the Susquehanna at the present time are due to an early entrance. In this system there are now, at least, no crayfishes which in present times are competitors with *O. p. propinquus*. *O. limosus* and *C. b. bartoni* have distinctly different habitat preferences. One wonders why it should not have achieved wider distribution had it entered early. It seems preferable to account for the localities near the confluence of the Chemung and Susquehanna proper by an entrance at Cayuta Lake, draining into Cayuta Creek (also known as Shephard's Creek). Under *O. immunis* it is pointed out that stream capture is taking place in the Cayuta Lake area at the present time. Figure 5 seems to indicate that in the restricted region involved, *O. p. propinquus*, the invader, is replacing *O. limosus* from the latter's home territory.

Three isolated localities for this species in the eastern Susquehanna (Unadilla River; NYSM 7006, 7009, 7011) shown in figure 5, might be accounted for by a southern outlet of glacial Lake Herkimer (in the Mohawk Valley) passing into the Susquehanna through the Unadilla Valley (Fairchild 1912: 39, plates 1 and 13). However, if this species is gaining territory in competition with *O. limosus* slightly further west, then one would expect it to have gained far greater territory here in the eastern Susquehanna if it arrived here at a much earlier time. I consider the three records to be a result of recent introductions.

The distributions of *O. p. propinquus* and *O. immunis* are similar, not only in the Susquehanna River system in New York, but throughout the State.

Five previously recorded New York localities are available for *O. obscurus*: Genesee River at Rochester (Hagen 1870: 70); Allegheny River drainage at Salamanca (Ortmann 1905c: 402-404); Cattaraugus Creek, Lake Erie drainage (Faxon 1914: 374); Mohawk-Hudson drainage (Nevin and Townes 1935); Lake Chautauqua, Allegheny drainage (Townes 1938).

New York localities for *O. p. propinquus* are given by Girard (1852: 88), Hagen (1870: 68-69), Faxon (1885c: 360; 1885b: 91; 1914: 373-374), Ortmann (1906: 363), Goodnight (1940a: 171; 1940b: 34), Creaser (1934) and Nevin and Townes (1935). Creaser discusses distribution in the Raquette River system and Nevin and Townes do the same for the Mohawk-Hudson. The other references cited list a total of 41 localities. None of these forms an exception to the distributional pattern in New York as determined in the present study.



Orconectes limosus

(FIGURE 5)

Outside of New York, the only locality records for this species which, up to the present time, have not been doubted by any students of crayfishes, lie in the States of Pennsylvania, Virginia, District of Columbia, Maryland and New Jersey.

Four locality records lie in drainage systems entirely outside the major distributional area of this species at a distance from the area of at least 130 miles. These records are: Niagara (Hagen 1870: 62), Lake Erie (Hagen 1870: 61), Lake Superior (Faxon 1885b: 87),

and Ontario (Huntsman 1915: 160). Faxon (1885b: 87) retains the localities Lake Erie and Niagara, but (1890: 629) drops the Lake Erie record because the specimens "... are too small to determine with certainty." Ortmann (1905a: 131-2) doubts the three older records and a year later (1906: 430) says, "No positive record from New York State is at hand (see DeKay, 1844, p. 23, and Paulmier, 1905, p. 117)."

I have seen the Niagara specimens (MCZ Crust. 179). As small as they are (the largest carapace length is 17.0 mm.) they are definitely *O. limosus*. Ortmann (1905a: 132) explains this record by suggesting that these specimens were put by mistake into a bottle containing *O. p. propinquus*. Hagen (1870: 62, 69) does give the same locality and collector (L. Agassiz) for these two species.

The Lake Superior specimens are apparently lost. Faxon (1885b: 87) reports them as being in the collections of the Boston Society of Natural History. In the summer of 1955, I was not able to locate them at the Boston Museum of Science or at MCZ.

The Lake Erie specimens were reported by Faxon (1885b: 87) as being in the collections of the Peabody Academy of Science. I am informed through conversation and correspondence with Dorothy E. Snyder of the Peabody Museum (Salem, Mass.) that this collection is not now at the museum. Some materials were moved from the Peabody Museum to the MCZ in 1942, but this collection apparently was not one of them. However, there is a specimen at MCZ (Crust. 306; new catalog 3800) which the Crustacea catalog reports as being received from the Peabody Academy of Science in November, 1885. The old label in the jar reads, "*Cambarus affinis*?, Lake Erie, F. W. Putnam." It may be that this is one of the Peabody Academy specimens in question. It is a female, carapace length 17.2 mm., and is not *Cambarus affinis* (= *O. limosus*). It is most like *O. p. sanborni*, for it has a seminal receptacle like *O. p. propinquus*, yet it lacks a rostral carina. This subspecies occurs in the Lake Erie watersheds of Ohio and Pennsylvania (Ortmann 1906: 439 and plate 42, figure 3).

The Ontario specimens were taken at Iroquois, a town on the St. Lawrence River about five miles west of Waddington, N. Y. The collector of these specimens, Dr. A. R. Cooper, wrote me on July 19, 1955, that he could not now remember the circumstances of collecting, in particular whether or not the crayfishes were local. On the basis of Huntsman's figures (1915: figures 8c, 9c, 10c and 12d) which are unquestionably *O. limosus*, the specimens were correctly identified, but Huntsman did not specifically state from which specimens

the figures were drawn. In August 1952, I collected at Iroquois and also directly across the river, but obtained only *O. p. propinquus* and *C. b. bartoni* (NYSM 6987, 6989).

In summary, the present status of these four records is: (1) the Niagara specimens are accurately identified, but a mixup of specimens might have occurred; (2) the Lake Superior specimens are apparently lost; (3) the Lake Erie specimens have been either lost, or, if a specimen now at MCZ is one of them, it is not, and probably therefore the rest were not, *O. limosus*; (4) there is no reason to doubt the Ontario record except because of the isolated locality. None of these records has been substantiated in the last 50 years of collecting on the U. S. borders of Lake Superior (Wisconsin: Graenischer 1913, Creaser 1932; Michigan: Pearse 1910, Creaser 1931) and Lake Erie (Ohio: Turner 1926, Rhoades 1943 and 1944b; Pennsylvania: Ortmann 1906) or in the St. Lawrence River drainages in New York (present study).

An old record for New York without specific locality, given by Hagen (1870: 62) is omitted by Faxon (1885b: 87). No reason is given for the omission, but it is presumably because of the lack of specific locality data. I have examined the collection (MCZ Crustacea catalog 270), a single female, and I consider it definitely to be *O. limosus*.

Mayer (1911) says, "In the neighborhood of New York we find three common species." However, no specific localities are given. Furthermore, of the three species, the locality for the figured specimen of *Cambarus bartoni* is given as Orange Mountains, N. J. The discussion of *Cambarus blandingi* appears to be taken from Abbott (1873: 80), and *Cambarus affinis* is mentioned in connection with its being "...commonly sold in the New York markets." I would hesitate to assign any one of these three species to the State on the basis of these statements.

Two specific localities for *Orconectes limosus* in New York are given by Osborne (1912: 924): Central Park Lake, New York City, and Prospect Park Lake, Brooklyn. His description and photograph of this species (Osborne 1912: 925) leave no doubt as to its identity. Townes (1937: 226) reports *O. limosus* at Coxsackie, Greene County, Hudson River drainage. Until the present study, these have been the only unquestioned specific New York localities.

Human agencies may have had something to do with the dispersal of *O. limosus*. Faxon (1885b: 89) says, "*C. affinis* is the common crayfish exposed to sale in the markets of New York and other eastern cities."

The entrance of *O. limosus* into New York State has probably been effected by separate entrances in the Delaware, Hudson and Susquehanna systems, perhaps following closely the recession of the ice.

Until the validity of northern records is ascertained it is hardly possible to discuss further the routes of dispersal of this species.

The nearest relatives of *O. limosus* are found in Kentucky, Southern Indiana and Missouri, and, as Ortmann points out (1905a: 114), this geographical isolation of *O. limosus* accompanied by morphological isolation indicates the antiquity of the *Limosus* section.

Cambarus robustus

(FIGURE 6)

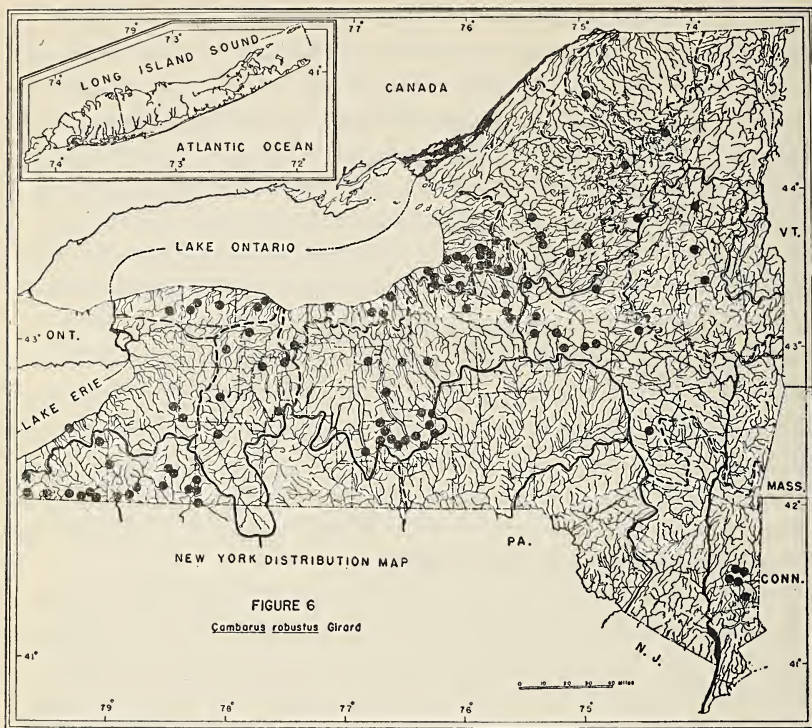
Ortmann (1906: 449) was unable to find *C. robustus* in the Susquehanna or Delaware drainages in Pennsylvania and it is apparently restricted in that State to the watersheds of the Allegheny River and Lake Erie. The one exception is Ortmann's record from Chartiers Creek, Allegheny County, and this stream enters the Ohio River opposite the entrance of the Allegheny.

In Ohio, which has been extensively surveyed for crayfishes, Turner (1926: 185, and map 5, p. 184) gives nine localities for *C. robustus* in the northeastern portion of the State in Lake Erie drainages. In addition he gives nine other localities in the Ohio River drainage. Seven are in the Scioto River system and have been referred by Rhoades (1944b: 96) to his *C. b. sciotensis*. Of the remaining two localities, one is Big Jelloway Creek, given by Turner (p. 185) as Knox County, but the record on his map 5 is in Licking County. The drainage here is apparently the Muskingum River. The other record is the Ohio River, Lawrence County, at the southern tip of the State. These last two localities may also be *C. b. sciotensis*.

Creaser (1931: 267-269, map 6) has plotted the range of this species in Michigan. It is apparently absent from Wisconsin (Creaser 1932: 336, table 1). The materials on which the records for this species at the periphery of its range are based should be reexamined wherever possible. This is particularly true to the south where there are records for the State of West Virginia (Faxon 1914: 388 and Newcombe 1929: 285). Records for Virginia, Maryland and Illinois, given by Faxon (1885b: 61 and 1890: 622) are subsequently dropped by him (Faxon 1914: 388).

Ortmann (1906: 392-3, 450) points out that the records he gives for *C. robustus* in Maryland, Virginia and Kentucky may be a different form.

Fowler (1912) does not report *C. robustus* from New Jersey, but he gives no specific account of how extensive his collecting was.



Fowler's description of *C. b. bartoni* seems to exclude *C. robustus* except possibly for the statement concerning the areola: "...with about three to five rows of punctures irregularly." His figures (plates 100, 101) are distinctly *C. b. bartoni* in shape of hand and rostrum.

In addition to the type locality, the other reports of *C. robustus* in Canada are mostly from near Toronto, Province of Ontario (Faxon 1885b: 61). However, Huntsman (1915) reports it from western Ontario also. Information from both Ontario and Quebec is much needed in order to define the limits of this species as well as of *C. b. bartoni* and *O. virilis* in Canada.

Thus, there is left, of records from the literature which have not been doubted, and including the New York distribution here presented, the following picture of the distribution of this species. *C. robustus*, as known at the present time, inhabits an area extending eastward to the Hudson River drainage system, and in the west to Michigan. To the north it is reported from Canada and to the south its boundaries are poorly defined, probably not entering the Ohio River drainage in the State of Ohio, and restricted to the Allegheny River and Lake Erie drainages in Pennsylvania. It is

absent from the Susquehanna and Delaware drainages in New York State.

A total of 15 specific locality records for *C. robustus* in New York is given by Hagen (1870: 80), Faxon (1885c: 358; 1885b: 61; 1898: 649; 1914: plate 3) and Ellis (1920: 250). Creaser (1934) reports the distribution of this species in the Raquette River system. None of these records is in disagreement with the general pattern of distribution in New York as established by the present study.

C. robustus has apparently originated from a present member of, or a stock ancestral to, *C. montanus*, and its region of origin appears to be southeastern Ohio or western West Virginia. From here it has migrated to the north and then to the east and west.

One might easily postulate that *C. robustus* and *O. obscurus* originated together in the same area, of course from different stocks. If, in the distributional summary based on Ortmann, which I have given under the distribution of *O. obscurus* and *O. p. propinquus*, the name *C. robustus* be substituted for *O. obscurus*, there is no apparent contradiction to the line of reasoning.

It is here suggested then that *C. robustus* differentiated in one of the tributaries (the Old Monongahela) of the preglacial Erigan River along with *O. obscurus*. Its dispersal, subsequent to the recession of the ice, has been basically the same as for *O. obscurus*, but with the difference that it has extended itself further to the north, west and east. This has been possible because, on reaching the Great Lakes drainages, *O. obscurus* found a close relative, *O. p. propinquus*, already occupying these areas. *C. robustus*, on the other hand, although having habitat preferences similar to those of *O. p. propinquus*, is much more distantly related to it and has a distinctly different life history. It is apparently much less in competition with *O. p. propinquus* than is *O. obscurus*. To the north and east, *C. robustus* occupies nearly the same range as *O. p. propinquus*, but has not extended as far west, and this is explained by *O. p. propinquus* having a more direct and earlier start in that direction. *C. robustus* arriving later, at a time when the glacial lakes were smaller, would have access to fewer stream systems.

Although *C. robustus* has progressed further to the north, east and west than has *O. obscurus*, it does not apparently extend as far south in the Allegheny River system. Ortmann (1906: 449) admits, however, that it may be in Forest, Venango and Armstrong Counties.

It should be noted further that the relationship between the present distributions of *C. robustus* and *C. b. sciotensis* is similar to the relationship between the present distributions of *O. obscurus*

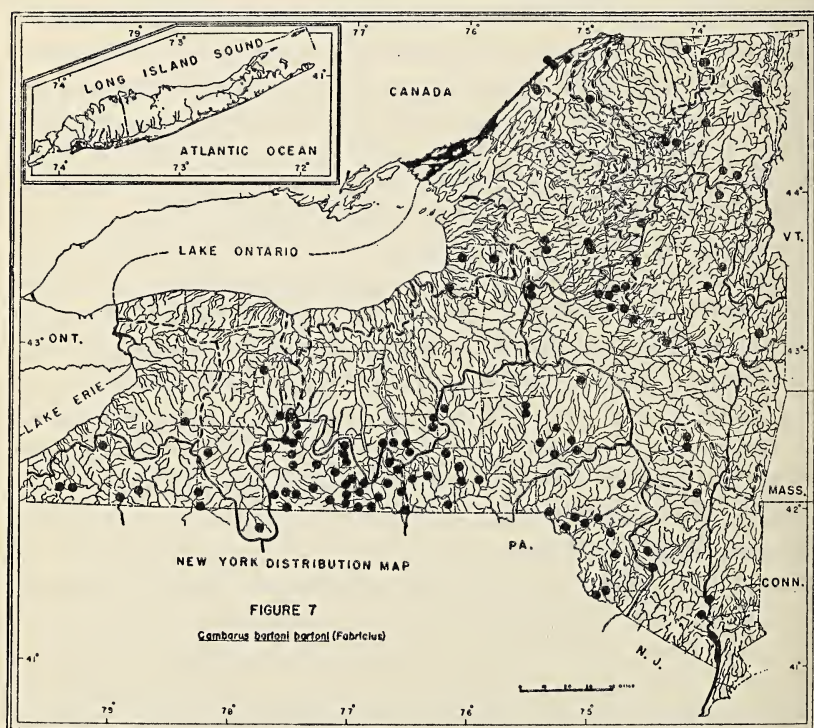
and *O. p. sanborni* (see Ortmann 1906: pl. 42, fig. 3). The line of reasoning applied by Ortmann (1906: 434-438) to the origins of *O. obscurus* and *O. p. sanborni* may equally well be applied to *C. robustus* and *C. b. sciotensis*. *C. robustus* is analogous to *O. obscurus* and *C. b. sciotensis* is analogous to *O. p. sanborni*. Here is evidence, in addition to morphological similarities, of the close relationship between *C. robustus* and *C. b. sciotensis*.

Ortmann (1905a: 121) places the origin of what is now the genus *Cambarus* at the southern extremity of the Appalachian system of mountains.

Cambarus bartoni bartoni

(FIGURE 7)

Records of *C. b. bartoni* in New York are given by Rafinesque (1817: 42, as *Astacus pusillus* and *A. ciliaris*), DeKay (1843: 22-23), Hagen (1870: 79), Smith, S. I. (1874: 639), Faxon (1885b: 60; 1885c: 358; 1914: 383-4), Ortmann (1905a: 134; 1906: 384), Paulmier (1906: 134), Creaser (1934), Nevin and Townes (1935) and Goodnight (1940b: 34, 38). Creaser and Nevin and Townes discuss distributions in the Raquette and Mohawk-Hudson Rivers respec-



tively. DeKay's report gives no specific localities, but is interesting because of its age. The remaining authors give a total of 38 specific, at least somewhat restricted, localities. None of these is in disagreement with the general pattern of distribution in New York as established by the present study.

C. b. bartoni probably occurs throughout New York. The regions in which it is absent on the distribution map are the Erie-Niagara drainages and the miscellaneous tributaries along the southern shore of Lake Ontario.

Tables 16, 17 and 18 show that material is poor for the Erie-Niagara system and furthermore, Faxon (1885*b*: 60) gives Niagara (Niagara Co.) and Forestville (Chautauqua Co.) as localities for this species. More collecting here will undoubtedly turn up at least a few more records.

There are no records in the literature for the occurrence of this species in the miscellaneous Lake Ontario tributaries where figure 7 shows it to be apparently lacking. The New York State Museum crayfish collection is particularly rich for this region, yet not one specimen of the present species has been collected. I think the reason for its absence here is the lack of suitable habitats. This is a lowland area with numerous slow, meandering streams, entirely different from habitat preferences of *C. b. bartoni* elsewhere. There is a record (Faxon 1885*b*: 60) for *C. b. bartoni* at Rochester in the Genesee River which is in the east-west center of the area in question. Certainly there are no physical barriers to its dispersal along the shore of Lake Ontario east and west from Rochester. One can most reasonably conclude that it is absent because there are very few suitable places for it to live.

The entrance of *C. b. bartoni* into New York was probably made at several points. It may have entered the Hudson directly, or through the Susquehanna into the Mohawk-Hudson by way of the Unadilla outlet (Fairchild 1912, plate 5). Its entrance into the Genesee could have been accomplished through a connection which persisted through stages three and four of Fairchild (1912, plates 11 and 12), or later (stage five) by way of what are now the Finger Lakes. The entrance of *C. b. bartoni* into the Allegheny River drainage probably took place outside of New York. From the Allegheny it may also have entered the Genesee through the Olean outlet.

Any consideration of dispersal of this species must take into account its habitat. As a mountain stream form it is particularly susceptible to dispersal by stream capture and its dispersal along

TABLE 16
Summary of crayfish collections in the New York State Museum taken during stream survey operations, 1926-1939

Drainage	Year ^a		Species	Oswego R.		L. Erie Niagara R.		L. Champlain		Grass, St. Regis & Salmon R.		Oswegatchie & Black R.		Hudson River						Raquette R.		Delaware R.				Susquehanna River				Allegheny R.		Misc. L. Ontario tribs.		Total
	Coll. b	Spec.		Coll.	Spec.	Coll.	Spec.	Coll.	Spec.	Upper —1932	Coll.	Spec.	Mohawk —1934	Coll.	Spec.	Lower —1936	Coll.	Spec.	1933	Coll.	Spec.	1935	Coll.	Spec.	East —1935	Coll.	Spec.	West —1937	Coll.	Spec.	1939			
<i>Cambarus b. bartoni</i>								4	4	1	1								1	76	9	14	5	36	64	5	7	3	5	90	235			
<i>C. robustus</i>	1	1						1	1	5	14	5	8	2	6												17	43	54	183	89	260		
<i>Cambarus sp.</i>																											2	2	1	1	5	5		
<i>Orconectes immunis</i>								1	3	2	2													1	3	7	15	37	90	62	155			
<i>O. limosus</i>												13	25	99	212								5	14	2	3	7	20		126	274			
<i>O. obscurus</i>	1	2										10	18													2	6	46	192	59	218			
<i>O. p. propinquus</i> ..	7	11	19	40	2	2	1	1				4	6	13	65												11	33	83	199	140	357		
<i>O. virilis</i>								2	10	1	1																			5	13			
<i>Orconectes sp.</i>																											4	4	1	2	3	6	12	
<i>Procambarus b. blandingi</i>																															3	5		
Total.....	8°	14	22	56	10	10	2	2	1	1	1	13	46	59	174	115	238	2	82	14	28	7	11	57	142	53	246	150	484	513	1,534			

^a No crayfish were saved from the Genesee R. (1926) or Long Island (1938) surveys.

^b Number of collections containing a given species.

^c Number of crayfish—containing collections taken during a given year, not the sum of the column of figures above.

TABLE 17
 NYSM crayfishes collected by D. W. Crocker in August 1952

Drainage Species	Oswego R.		L. Erie-Niagara R.		L. Champlain		Grass, St. Regis & Salmon R.		Oswegatchie & Black R.		Hudson R.		Delaware R.		Susquehanna R.		Total	
	Coll. ^a	Spec.	Coll.	Spec.	Coll.	Spec.	Coll.	Spec.	Coll.	Spec.	Coll.	Spec.	Coll.	Spec.	Coll.	Spec.	Coll.	Spec.
<i>Cambarus b. bartoni</i>			1	4	1	2	3	19			2	9	2	10	7	83	16	127
<i>C. robustus</i>	5	35	1	6							5	18					11	59
<i>Orconectes immunis</i>			1	13							4	6			1	3	6	22
<i>O. limosus</i>											2	52	1	14	7	44	10	110
<i>O. obscurus</i>	2	30 ^b	1	31							3	183 ^b					6	244
<i>O. p. propinquus</i>	7	117 ^b	2	47	4	57	3	12	2	10	4	84 ^b			4	84	26	411
<i>O. virilis</i>			1	13	1	8					1	44					3	65
<i>Procambarus b. blandingi</i> ...											1	6					1	6
Total.....	8 ^c	182	3	114	5	67	3	31	2	10	11	402	3	24	11	214	46	1,044

^a Number of collections containing a given species.

^b In these collections it was difficult to distinguish between *O. obscurus* and *O. p. propinquus* and therefore the number of specimens assigned to these species may not be correct.

^c Number of collections made in a given drainage, not the sum of the column of figures above.

TABLE 18
Summary of New York State crayfishes in the personal collection of the author through July 12, 1951

Drainage Species	Genesee R.		Oswego R.		L. Champlain		Grass & Salmon R.		Oswegatchie & Black R.		Hudson R.		Raquette R.		Susquehanna R.		Allegheny R.		Misc. L. Ontario tribs.		Total	
	Coll. ^a	Spec.	Coll.	Spec.	Coll.	Spec.	Coll.	Spec.	Coll.	Spec.	Coll.	Spec.	Coll.	Spec.	Coll.	Spec.	Coll.	Spec.	Coll.	Spec.	Coll.	Spec.
<i>Cambarus b. bartoni</i>	5	25	13	86	4	12	1	6	4	7			1	2	10	55	3	14			41	207
<i>C. robustus</i>	8	37	42	550	1	8			7	87	1	1	1	6			8	69	3	31	71	789
<i>Cambarus sp.</i>																	1	1			1	1
<i>Orconectes immunis</i>	3	7	14	491			1	1													18	499
<i>O. limosus</i>												4	23			4	104				8	127
<i>O. obscurus</i>	9	117							3	9	1	19	1	1			8	122			22	268
<i>O. p. propinquus</i>	7	119	34	893	2	2	1	8	3	19			2	18	4	99			4	75	57	1,233
<i>O. virilis</i>					1	1	1	5													2	6
<i>Orconectes sp.</i>																					2	4
Total	20 ^b	305	69	2,020	8	23	3	20	10	122	6	43	4	27	17	262	9	206	5	106	151	3,134

^a Number of collections containing a given species.

^b Number of collections made in a given drainage, not the sum of the column of figures above.

the Appalachian system, independent of drainages, is evidence that this has actually occurred.

Of the general distribution of *C. b. bartoni*, Ortmann (1905a: 122) states, "This species has followed, in its dispersal, chiefly in the direction of the strike of this mountain chain [Appalachian] and reaches now from Tennessee to Maine and New Brunswick [it is also in Ontario (Huntsman 1915)]. Eastward it hardly descends to the Atlantic plain, at any rate it does not spread over it, and westward it goes as far as Indiana, always preferring smaller streams in mountainous or hilly regions."

The origin of the genus *Cambarus*, as already noted under *C. robustus*, has been placed by Ortmann at the southern extremity of the Appalachian system of mountains.

OTHER NEW YORK SPECIES

Three crayfish species, *Cambarus fodiens* (Cottle), *C. d. diogenes* Girard and *C. uhleri* Faxon, may occur in New York in addition to the eight forms already discussed. All three are members of the *Diogenes* section of the genus and are burrowing species.

C. fodiens (= *C. argillicola* Faxon) is known from Ontario through Ohio, Michigan, Indiana, and Illinois (Hobbs, 1948: 229). It should be searched for in western and northern New York in marshes and temporary ponds.

C. uhleri is known from Maryland where it inhabits salt marshes and brackish or fresh-water ditches. Similar habitats in New York may possibly support populations of this species.

C. d. diogenes has been reported 75 miles from the New York border in Ohio (Turner, 1926: 187, map 6), 60 miles from the New York border in Pennsylvania (Ortmann, 1906: 405) and 30 miles from the New York border in New Jersey (Fowler, 1912: 352).

Synonymies for these three species and descriptions and figures of *C. fodiens* (as *C. argillicola*) and *C. uhleri* are given in Faxon (1885*b*). Ortmann (1906) describes *C. d. diogenes* in Pennsylvania.

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INTRODUCTION

During 1953 and 1954, samplers were operated in 35 localities in New York State to determine the abundance of various microscopic organic particles in the air. The Durham sampler, a device approved by the Pollen Survey Committee of the Research Council of the American Academy of Allergy, was used at each station. The samplers were in operation for 200 days each growing season: April 1 through October 17 during 1953 and March 15 through September 30 during 1954. During these periods over 14,000 samples were obtained requiring approximately 2,500,000 determinations. The data for 1953 are now ready and are presented here. The 1954 samples are still being studied.

The localities where sampling stations were installed were chosen to place the samplers about 50 miles apart and, where possible, near centers of population. Fortunately, dependable cooperators were found to service the stations seven days a week throughout the sampling periods. And this with no remuneration other than the satisfaction of contributing to a worthy cause!

The general location of these stations is shown on the map (page 20). The specific locations, names of cooperators, types of installation and other pertinent data are found in the descriptions of the individual localities.

Most of the samplers were installed on the roofs of buildings, including water filtration plants (8), sewage disposal plants (7), hospitals (6), schools (3) and other public buildings (5).

The particles that were caught, identified and recorded were primarily pollen grains and fungus spores but included spores of ferns and mosses, alga cells, plant hairs and insect scales.

PROCEDURE

The samplers were installed to give the best possible samples for the area and allow reasonably easy access for daily servicing. They were mostly well above ground to prevent undue influence of local conditions and a sufficient distance from objects that would obstruct or divert air movement. The sampler uses greased microscope slides on which the tiny airborne particles are impinged. The slides were uniformly greased in the laboratory in Albany. During 1953 this was with petrolatum jelly. Experiments conducted by us indicated that

silicone grease worked equally well, gave the same readings and lessened the danger of melting in summer heat, so it was used in 1954.

Boxes of 25 slides each were mailed periodically to the cooperators who exposed each slide for a 24-hour period on consecutive days. The slides were changed each morning at the same time which varied somewhat from station to station but usually at 9 a.m. The cooperator wrote the date of exposure on the frosted end of each slide and periodically mailed the exposed slides to our laboratory.

As soon as convenient, our technicians stained the slides with Calberla's solution, which employs basic fuchsin as a dye, and added a No. 1, 22 mm. square cover glass. Identification and counting was done using a binocular microscope with an apochromatic lens system and a built-in light. Most of the determinations were made at 100 diameters but greater magnifications were used when necessary. An extensive collection of check slides, from authentically identified material, and several useful publications were constantly at hand.

Two square centimeters of each sample were examined and the data recorded on tally sheets. If counts were low, three or four square centimeters were examined. The data were reported as the average per square centimeter.

The tally sheets were processed by the Bureau of Statistical Services of the State Education Department where the data were recorded on IBM cards allowing the sorting and tabulation of the information for study and presentation as graphs.

In Albany, two sampling stations were installed approximately one mile apart to determine the uniformity of particles in the air over a given locality. These stations were operated continuously from April 1, 1953, through September 30, 1954. During the summer of 1955, two samplers were operated 15 feet apart on the roof of the Education Building in Albany. The data from these supplementary stations are mentioned under Station 25.

The primary purpose of this survey is to furnish information of value in studies on pollinosis (hayfever). Although it is designed for use by patients and physicians who need to know what, where and when organic particles are in the air in sufficient quantities to cause medical concern, the presentation and discussion is from a botanical standpoint only.

ACKNOWLEDGMENTS

Our first and most grateful thanks go to the many cooperators who accepted the responsibility for collecting the daily samples and mailing them to the Albany laboratory. Many of them assisted in the installa-

tion of the sampling stations and several constructed elaborate devices to insure that proper samples were obtained. They are individually named in the descriptions of sampling stations.

Numerous persons helped in various ways but special thanks are due the following :

Fay Hyland, professor of botany, University of Maine, whose similar survey in Maine has been used as a model, has been continuously generous with much appreciated advice.

F. Wellington Gilcreas, formerly assistant director, Division of Laboratories and Research, New York State Department of Health, for advice, loan of equipment and making several of the research laboratory facilities available.

Doris McGlynn, now on the staff of the State Department of Health, was responsible for most of the routine identification and counting. She handled all of the samples for 1953 as well as the 1954 samples through most of the tree pollens. Assistance in completing the samples for 1954 and preparation of the graphs has come from Margaret Curtin, Charles Downing and Donald Lewis. Mrs. Emily Dixon helped with the analysis of data and planning of graphs.

Stanley J. Smith, curator of botany in the New York State Museum, has assisted in numerous ways, especially in the identification of troublesome plant parts and even taking time from his own research to help in the installation of the sampling stations. John Wilcox, curator of entomology, has frequently helped with the identification of insect parts.

Dr. Louis H. Conger of the Bureau of Statistical Services of the State Education Department has been our source of advice on mathematical matters. Without the aid of the bureau's machine room, the analysis of the data would have taken a much longer time.

O. C. Durham of Abbott Laboratories, North Chicago, Illinois, advised relative to procedures acceptable to the Pollen Survey Committee of the American Academy of Allergy.

PLANTS PRODUCING AIRBORNE POLLEN

Pollen is produced by flowering plants and conifers. The individual grains of pollen are too small to be seen with the unaided eye but in quantity they appear to be a yellowish powdery mass. The conifers and some flowering plants are wind-pollinated. Such plants usually produce large quantities of dry buoyant pollen grains. Most flowering plants are insect-pollinated ; their pollen is not transported any appreciable distance by air currents. For convenience, those plants that

produce buoyant pollen in large quantities may be divided into trees, grasses and weeds. Most airborne tree pollens are shed during spring and early summer, the grasses during midsummer while the weed pollen is in the air during the late summer and fall. Overlaps occur as will be seen from an examination of the graphs.

Trees

While the order of appearance of the various tree pollens varies slightly among localities, the average order of appearance in quantity is somewhat as follows: juniper (*Juniperus*), hazel (*Corylus*), alder (*Alnus*), willow (*Salix*), elm (*Ulmus*), maple (*Acer*), poplar (*Populus*), larch (*Larix*), birch (*Betula*), sweet fern (*Comptonia*), blue beech (*Carpinus*), hop hornbeam (*Ostrya*), oak (*Quercus*), fir (*Abies*), hemlock (*Tsuga*), sycamore (*Platanus*), pine (*Pinus*), spruce (*Picea*), beech (*Fagus*), ash (*Fraxinus*) and hickory (*Carya*). Small amounts of walnut (*Juglans*), basswood (*Tilia*), cedar (*Thuja*), tree-of-heaven (*Ailanthus*) and black gum (*Nyssa*) were recorded from some stations.

It is very difficult to separate the pollen of birch, sweet fern, blue beech, hop hornbeam, alder and hazel. The last two are mostly shed earlier than the others and cause less confusion. Birch pollen exhibits variation due to the different species. During May 1953, especially between the 5th and 15th of the month, nearly all of the stations collected pollen that did not match well with birch and did not correlate with the occurrence of blue beech and hop hornbeam. It was therefore recorded as unidentified pollen and for most of the stations the amount was too low to warrant mention. However, for several stations amounts were recorded too large to ignore. This type of pollen was not seen in the 1954 samples and it now appears likely that at least some of the 1953 unidentified pollen should be included with birch. It is probable that the counts of birch, especially for May 9, 10 and 11, should be increased for Gloversville, Liberty, Turin and Oneonta.

There is some question about the counts on sweet fern. Its occurrence on the graphs does not correlate well with its occurrence in the State. It is possible that some birch pollen has been recorded under sweet fern. Further remarks will be postponed until the 1954 data are studied; until then it may be well to regard the sweet fern data with suspicion.

Grasses

There are over 400 species of grasses in New York but it is likely that most of the grass pollen is from 20 to 25 of the common species. Among those producing pollen in large quantities are: sweet vernal grass (*Anthoxanthum odoratum*), timothy (*Phleum pratense*), redtop

(*Agrostis alba*), Kentucky blue grass (*Poa pratensis*), and orchard grass (*Dactylis glomerata*). We found it impossible to distinguish the different grasses by their pollen grains.

Weeds

In their production of pollen, all of the weeds are of minor importance, except ragweed (*Ambrosia*). The total count of the latter exceeded that from all other entities, with the exception that the total grass pollen was slightly more. Most of this pollen is from short ragweed (*A. artemisiifolia*) but in some areas giant ragweed (*A. trifida*) supplies large amounts. The time of year when ragweed will be pollinating can be predicted rather closely for, unlike most plants, the flowering period is dependent upon latitude. When the daylight period reaches a certain length the ragweed plants come into bloom regardless of their size.

Experiments conducted by O. C. Durham indicate that the factor 3.6 may be used to convert the number of ragweed pollen grains per square centimeter of greased slide surface, when exposed in the Durham sampler for 24 hours, to the average number per cubic yard of air. Thus a count of 7 as shown on the ragweed graph would indicate an average of 25 grains per cubic yard. The first three columns of the following figures are converted to the cubic yard basis. From such data the "ragweed pollen index" is obtained by assigning one point for each day when the count reaches or exceeds 25, one point for each 100 grains of pollen on the day of the highest count and one point for each 200 grains of pollen in the seasonal total.

STATION	NUMBER OF DAYS WITH COUNTS OF 25 OR GREATER	MAXI- MUM DAILY COUNT	TOTAL SEASONAL COUNT	RAGWEED POLLEN INDEX
1. Montauk Point	3	50	302	5
2. Riverhead	21	490	2,941	41
3. Farmingdale	27	270	2,898	44
4. Yonkers	25	191	2,300	38
5. Newburgh	19	155	1,897	30
6. Zena	13	76	814	18
7. Belle Ayre Mt.....	18	173	1,382	27
8. Liberty	17	284	1,678	28
9. Oneonta	19	284	2,250	33
10. Binghamton	20	158	1,757	31
11. Cortland	21	259	2,599	37
12. Elmira	27	306	2,660	43
13. Hornell	21	216	2,272	34
14. Olean	28	216	2,304	42
15. Celoron	24	447	2,538	41
16. Springville	25	371	3,910	49
17. Lockport	33	565	6,494	71
18. Perry	31	2,376	11,722	114
19. Rochester	31	994	7,340	79

STATION	NUMBER OF DAYS WITH COUNTS OF 25 OR GREATER	MAXI- MUM DAILY COUNT	TOTAL SEASONAL COUNT	RAGWEED POLLEN INDEX
20. Geneva	29	518	4,611	57
21. Oswego	18	256	2,844	35
22. Syracuse	24	472	3,478	46
23. Utica	23	670	3,906	50
24. Gloversville	18	245	1,829	29
25. Albany	15	176	1,602	25
25A. Albany	19	295	2,801	35
26. Hudson Falls	20	407	2,524	37
27. Ticonderoga	18	252	1,570	29
28. Indian Lake	10	222	1,091	17
29. Turin	10	72	738	12
30. Watertown	21	572	3,215	43
31. Wanakena	10	83	760	15
32. Saranac Lake	18	461	2,494	34
33. Dannemora	12	140	1,138	19
34. St. Regis Falls.....	17	443	2,373	33
35. Ogdensburg	21	666	3,564	46

Other weeds that produced sufficient buoyant pollen to be recorded on at least some of the graphs are, in order of their appearance: dock (*Rumex*), plantain (*Plantago*), pigweed (*Chenopodium* and *Amaranthus*), wormwood (*Artemisia*), marsh elder (*Iva*) and goldenrod (*Solidago*).

FUNGI

The total number of fungus spores for the season from the stations usually closely approached (and often surpassed) the total number of pollen grains. *Cladosporium* (including *Hormodendrum*) gave the highest readings, often being more than half the total count. *Alternaria* averaged second in abundance. It is probable that some *Stemphylium* spores were included in the counts for *Alternaria* as the spores of these genera are difficult to distinguish. In the counts of *Fusarium* it is likely that we have included spores of *Cylindrocarpon* and possibly *Curvularia*. Spores of rusts and smuts were recorded as such whenever possible but undoubtedly some were tallied under miscellaneous fungi.

Most fungi are impossible to recognize from spores alone. It is extremely likely that most of the spores recorded as miscellaneous fungi were from *Aspergillus* and *Penicillium* but included many from *Pullularia*, *Mortierella*, *Epicoccum*, *Botrytis*, *Phoma* and various mushrooms.

A multicellular spore was always counted as a single spore but a clump of spores was counted (or estimated) as the number of individual spores in the clump. Some of the high daily counts are due to one or more large clumps; these are often specifically mentioned under the discussion for each station. Bits of fungus tissue (hyphae) were recorded as spores.

MISCELLANEOUS

Ferns

The spores of most ferns are apparently too heavy to be plentiful in the air far from the source. Our counts include the club mosses (*Lycopodium*) with the true ferns (*Polypodiaceae* and *Osmundaceae*). The total for fern spores was roughly 3 percent of total pollen. Spores of the horsetails (*Equisetum*) were encountered occasionally.

Mosses

It is possible, though not probable, that the low counts for mosses are due to our inability to recognize them as such. If so, some of them are included with the ferns.

Algae

Small amounts of alga cells and filaments were encountered, but never in important amounts.

Plant Hairs

Our records from approximately 15,000 samples show plant hairs on every one. The counts were usually very high; too high to be conveniently included on the graphs with pollen and spores. At the Albany stations 25 and 25A, which were operated continuously from spring 1953 to fall 1954, plant hairs were found daily during the winter. Plant hairs vary greatly in size and no attempt was made to separate on that basis or on any other characteristic. With such high counts, the averages would be uniform and quite comparable between stations. Further discussion is best left until the 1954 samples are analyzed.

Animal Parts

Scales of insects were usually common and often abundant in the samples. They have been recorded but are not included in the present graphs. This category is comprised of tiny roundish scales, long narrow scales (hairs), portions of wings, legs and even whole insects (usually mites).

Hairs of animals such as dogs, cats, horses and bats and down from birds were occasionally noticed but were never common.

LIST OF STATIONS

1. Montauk Point

Cooperators: for 1953, Archie W. Jones, B.M.1, Montauk Point Light Station; for 1954, C. E. Schumacker who succeeded Mr. Jones as B.M.1.

The sampler was on the lawn about 70 feet from the lighthouse. It was 6 feet above the ground which is 60 feet above sea level. There were few plants that produce airborne pollen in the immediate vicinity of the sampler. A few flowers of crab grass (*Digitaria*) escapes the lawnmower. Bayberry (*Myrica*) is abundant on the east side several hundred feet away.

As would be expected from a station nearly surrounded by water, the total count from Montauk Point was the lowest of all the stations. This may be due, in part, to the early season causing juniper, elm, maple and poplar to shed pollen during March. The highest total count was from grass, with birch following a close second. The ragweed count was much lower than at any other station, with less than half the number of particles recorded for the next lowest (Turin) and approximately one-tenth that of Riverhead and Farmingdale.

2. Riverhead

Cooperator: Dr. Stuart Dallyn, director, Long Island Vegetable Research Farm.

This station is 3 miles northeast of Riverhead and 1 mile south of the Sound, at an elevation of 100 feet. The sampler was 25 feet above the ground and 3 feet above the roof of a flat-topped building, well in the open and surrounded by flat farmland. It was lowered by rope and pulley for changing the slides.

It is likely that the low counts for juniper, elm, poplar, maple and alder are due to lack of March samples. Maple, alder, hemlock and cedar were too low to warrant inclusion. Smut spores were too sporadic to graph: 11 on June 7, 6 on October 3 and 3 on October 15. There were traces of blue beech, hop hornbeam, black gum and tree-of-heaven in May.

3. Farmingdale

Cooperator: Dr. Louis Pyenson, Long Island Agricultural and Technical Institute.

The sampler was mounted on the roof of one of the Institute buildings, attached to an unused chimney. This locality is 90 feet above sea level; the sampler was 25 feet above the ground and in the open, being surrounded by greenhouses, low shrubs and mowed lawn. The nearest trees were more than 100 feet distant: pine, maple, elm and cedar. There are many small spruce trees in the vicinity but probably too young to shed pollen.

The low counts for juniper, elm, poplar, maple and alder may be due to lack of March samples. Alder, hemlock and cedar were too low

to include. *Fusarium* spores were occasionally seen but too sporadic to graph. There was a small amount of hazel in April and of blue beech, hop hornbeam, tree-of-heaven and black gum in May.

4. Yonkers

Cooperators: for 1953, Arthur Wallach, director, Division of Environmental Sanitation, Department of Public Health, Yonkers; for 1954, George J. Kupchik, who succeeded Mr. Wallach as Director.

This station is at the health center building which is 200 feet above sea level. The sampler was mounted on the roof parapet over 100 feet above the ground entirely free from anything that would divert normal air currents. It was well above plants producing airborne pollen such as the usual street trees, mostly elm and maple.

The low counts for juniper, elm, poplar, maple and alder are likely due to lack of March samples. There were small amounts of blue beech, tree-of-heaven, hop hornbeam and black gum in May.

5. Newburgh

Cooperator: John F. Kingsley, superintendent of water.

This station was located at the southwest edge of the city at 240 feet above sea level. The sampler was on the roof of the filtration plant, well in the open. The usual street trees are apparently the only near source of airborne pollen in quantity.

Low counts for juniper, alder and perhaps poplar and elm may be due to lack of March samples. The relatively high count for sycamore may be due to local street trees. There was a small amount of blue beech and traces only of hop hornbeam, black gum and tree-of-heaven.

6. Zena

Cooperator: William Colsten, chief filter plant operator, Kingston Water Department.

This station was 400 feet above sea level. The sampler was some 30 feet above the ground, mounted on the peak of the gable roof of a filtration plant building, well in the open. Trees in the vicinity were sugar maple, red oak, sycamore, hickory, white pine and ash. The lawn on the south and west close to the building had plantain, dock and daisy fleabane (*Erigeron*).

Probably much of the juniper and elm pollen was shed before April and perhaps poplar also. During May there were small amounts of blue beech and traces of hop hornbeam, tree-of-heaven and black gum.

7. Belle Ayre Mountain

Cooperator: Arthur G. Draper, superintendent, Belle Ayre Mountain Ski Center.

This station was our highest above sea level : 3,325 feet. The sampler was perched 30 feet above the ground on top of the tower at the upper end of the ski lift. It was in the open ; the nearest trees, beech and maple, being 30 feet away.

The count for ragweed indicates the situation on Belle Ayre Mountain and does not reflect the condition at Pine Hill in the valley, where the ragweed count is known to be low. There was some blue beech and traces of hop hornbeam, tree-of-heaven and black gum.

8. Liberty

Cooperator : Henry Eichenauer, superintendent of Sewage Disposal Plant.

This station was at the Sewage Disposal Plant, at an elevation of 1,400 feet above sea level. The sampler was 20 feet above the ground and in the open.

During May, especially on the 8th, 9th and 10th, there were large amounts of pollen that could not be identified. It was probably birch or blue beech. Also during May there were traces of hop hornbeam, tree-of-heaven and black gum. Smut spores were not graphed; the total was high but due to one clump of 170 grains on September 7; otherwise low and sporadic.

9. Oneonta

Cooperator : C. M. Taylor, superintendent of water ; assisted by Frank Adamowicz.

This station was at the Sewage Disposal Plant, 1,070 feet above sea level. The sampler was on a flat roof 20 feet above the ground. There were hayfields nearby and a few trees : elm, sycamore, beech and willow. A forested area on the south is of mixed woods, mostly maple and pine with some hemlock.

Unidentified pollen collected on May 9 and 10 may be birch or blue beech.

10. Binghamton

Cooperator : H. G. Koach, administrator of Binghamton City Hospital.

The sampler was on the roof of the hospital, about 50 feet above the ground, which is 870 feet above sea level. Plants in the vicinity producing airborne pollen are the usual street trees : elm, maple and sycamore.

This station began operation on April 3. It is probable that juniper, alder, willow, elm and poplar had shed some pollen during March.

11. Cortland

Cooperator: H. B. Holcomb, superintendent of Sewage Treatment Plant.

This station is at the Sewage Treatment Plant, 1,100 feet above sea level. The sampler was on the flat roof, about 20 feet above the ground. The station is surrounded by hayfields. Along the river close by there are willows and some elms. The outlying woods are mostly maple with some beech and occasional poplar and walnut.

Juniper and alder had mostly shed during March; probably some elm, poplar and maple also. The high count for grass may be due to the nearby hayfields.

12. Elmira

Cooperator: J. W. Colby, assistant superintendent of Arnot-Ogden Memorial Hospital.

The sampler was mounted about 50 feet above the ground on the roof parapet of the hospital, which is 880 feet above sea level. The station is surrounded by the usual street trees: maple and elm. There are a few spruce and pine trees on the hospital grounds.

Probably juniper, alder and elm had shed pollen during March and perhaps also poplar and maple. During May, there were traces of blue beech and tree-of-heaven.

13. Hornell

Cooperator: J. G. Cary, superintendent of water.

This station is at the Water Filtration Plant, 1,400 feet above sea level. The sampler was perched on the peak of the gable roof, 25 feet above the ground, of a building near the top of a hill. This hilltop is covered with young growth, mostly poplar (trembling aspen). On the north is a deep gorge with elm, maple, oak, blue beech, hop hornbeam, willow and scattered hickory. On the west are farms with hayfields. Plantain is abundant on the lawn near the station.

Probably much juniper, alder and elm had shed during March. It is very likely that the record for sweet fern is too high; this station had the highest count for this plant; the known distribution does not warrant it; its pollen is easily confused with birch.

14. Olean

Cooperator: Alfred H. Mann.

This station is at the Sewage Disposal Plant, 1,420 feet above sea level. The sampler was 15 feet above the ground and in the open, except for cedar trees nearby that are a few feet taller. Along the river

near the station are elm, maple and willow. Goldenrod is abundant in the area.

15. Celoron

Cooperator : Homer Feidler, Sewage Treatment Plant operator.

The station is at the Sewage Treatment Plant, 1,320 feet above sea level. The sampler was on the roof, 15 feet above the ground and in the open. The nearest trees were willow and poplar. Elm and maple were scattered on all sides. There were two small, but flowering, cedars planted beside the building. A small swamp of cattail (*Typha*) was just east of the station. Goldenrod was plentiful. There were a few plants of plantain, pigweed (*Chenopodium*) and short ragweed nearby.

16. Springville

Cooperator : Elmer Ganschow, superintendent of water.

The sampler was 15 feet above the ground on the roof of a pumping station, 1,350 feet above sea level. The sampler was in the open, being surrounded by lawn and a large schoolyard. Farther away were houses, street trees (mostly sugar maple) and weed patches. Other trees in the area are pine, elm, willow and spruce.

It is possible that one or more high points on the graph for maple may be due to the sugar maples nearby and the low position of the sampler.

17. Lockport

Cooperator : Roger Foltz, superintendent of Water Filtration Plant.

This station is at the filtration plant, 620 feet above sea level. The sampler was on a corner of a flat roof 25 feet above the ground and more than 50 feet from a higher part of the building. There were large hayfields near and the usual street trees: maple and elm, also poplar and willow.

The large amount of grass pollen recorded may be due, in part, to the hayfields in the vicinity. This was the second highest count for grass; being surpassed only by Turin.

18. Perry

Cooperator : Ralph Laney.

This station is at the Perry Waterworks, 1,380 feet above sea level, on the shore of Silver Lake. The sampler was only 12 feet above the ground but in the open on a rise above the lake. The nearest trees were 100 feet distant, mostly elm. Willow, maple and elm fringe the lake.

The ragweed count at Perry was the highest for all stations with the high point (September 4) reaching 660 grains per square centimeter

or approximately an average of 2,400 per cubic yard of air. The slides for July 19 and 20 were knocked out by young sparrows so the data were not used.

19. Rochester

Cooperator: Dr. John M. MacMillan, director of Iola Sanatorium.

This station is at the Sanatorium, at the south edge of the city, at an elevation of 550 feet. The sampler was on a flat roof, in the open, approximately 50 feet above the ground. Trees producing airborne pollen in the immediate vicinity are: sycamore, maple, spruce and ash. There is quite a bit of cultivated farmland in the area.

The high counts for *Cladosporium* on July 23 and miscellaneous fungi for September 13 are due primarily to large clumps of spores.

20. Geneva

Cooperator: Robert E. Johnson, administrator of Geneva General Hospital; assisted by Andrew Christensen, maintenance engineer.

This station is at the Hospital, 520 feet above sea level. The sampler was on the roof parapet, in the open, approximately 50 feet above the ground. Plants producing airborne pollen in the vicinity are the usual shade trees, mostly elm.

21. Oswego

Cooperator: Dr. George E. Pitluga, professor of science, Teachers College, State University of New York.

The station is at the College, 320 feet above sea level. The city is on the east; Lake Ontario on the north and west. The sampler was on the flat roof of the Union Building, in the open, approximately 30 feet above the ground. It was surrounded by lawn and campus trees, mostly maple, spruce, poplar and birch.

22. Syracuse

Cooperator: for 1953, William P. Gyatt, superintendent of the Bureau of Sewage Treatment; for 1954, Joseph D. Kieffer, who succeeded Mr. Gyatt as Superintendent.

The station is at the Sewage Disposal Plant, near the south end of Onondaga Lake, 380 feet above sea level. The sampler was mounted, 30 feet above the ground, above the roof of the building. It was well in the open on a platform that was lowered, by means of rope and pulley sliding the platform down guiding rods, for changing slides. Plants producing airborne pollen in the vicinity are street trees, mostly elm and poplar. A swamp between the station and the lake has cattail (*Typha*) and reed grass (*Phragmites*).

The station was operated from April 17 to October 12 during 1953. The lack of pollen from juniper, alder, poplar and low counts from willow, elm and maple may be due to their shedding before samples were taken.

23. Utica

Cooperator: H. F. Hoffman, senior public health engineer.

The station was at the YMCA Building, 500 feet above sea level, during 1953. The sampler was on the roof, well in the open, approximately 100 feet above the ground. During 1954 the sampler was on the roof of the Health Office Building, about 40 feet from the ground. Plants producing airborne pollen are essentially the same in the vicinity of both stations, being the usual street trees, mostly elm and maple.

Probably some alder, juniper, poplar and elm was shed during March. The uniformity of counts from July 21 through July 27 is because one slide was left on the sampler for those seven days; each day's record was obtained by dividing the total count by seven.

24. Gloversville

Cooperator: Stuart Heald, filtration plant operator.

This station is the Gloversville Water Works, approximately 2 miles north of the city, at 1,040 feet above sea level. The sampler was on the roof parapet, in the open, about 25 feet above the ground. There is a pine plantation nearby on the north.

The high count for pine on May 18 is likely due to the proximity of the sampler to the plantation. On May 8, 9, 10 and 11 there was quite a bit of pollen that could not be identified; it is likely that some of it was birch.

25. Albany

Cooperator: John Bartnick, custodian, New York State Museum.

This station is the Education Building on Washington Avenue in downtown Albany, 160 feet above sea level. The sampler was on the roof, in the open, 140 feet above the ground. Plants in the vicinity producing airborne pollen are the usual city trees, mostly elm, maple and tree-of-heaven.

A comparison of graphs for the two Albany stations, 25 and 25A will indicate the amount of variation that may be expected between samplings in the same general area but separated by a mile or so. Experiments are now being conducted to determine the effect of height above ground and local weather conditions on the pollen count. The two samplers operated 15 feet apart during 1955 gave rather uniform readings.

25A. Albany

Cooperator: Miss Eleanor Weeber, sanitary chemist, Division of Laboratories for Sanitary and Analytical Chemistry, New York State Department of Health.

This station is at the Health Department's Division of Laboratories and Research on New Scotland Avenue, 220 feet above sea level. The sampler was on the roof parapet, 70 feet above the ground.

26. Hudson Falls

Cooperator: J. A. Fitzgerald; assisted by Peter Keegan.

This station is the Sewage Treatment Plant, 240 feet above sea level. The sampler was mounted on top of an 8-foot upright column on the roof of the Plant, which placed it approximately 25 feet above the ground and in the open. Plants producing airborne pollen in the vicinity are box elder maple, elm, oak, poplar, pine and willow. There were small amounts of ragweed nearby. Forests in the area are of spruce, fir, blue beech, maple, birch and some larch.

The high count for miscellaneous fungi on July 24 is due to a large clump of spores.

27. Ticonderoga

Cooperator: Herbert Barber; assisted by Fred Warren.

This station is the Moses-Ludington Hospital, 200 feet above sea level. The sampler was on the roof, above the parapet, with no obstruction to modify air currents nearer than 60 feet. It was approximately 50 feet above the ground. Plants producing airborne pollen in the vicinity are elm, maple, poplar, birch and cedar. On the west side are hayfields with occasional elms. Forests in the general area are mixed hardwoods.

On May 11 and 12 there were rather large amounts of pollen that could not be identified. It is likely that some of it was birch.

28. Indian Lake

Cooperator: Guy Pelon, superintendent of water.

This station is the home of Mr. Pelon in the village, 1,740 feet above sea level. The sampler was mounted 25 feet above the ground on top of a pole in the open. The sampler was lowered by rope and pulley for changing slides. Principal plants producing airborne pollen in the immediate vicinity of the sampler were grasses as the pole was in a hayfield. Trees in the area are the typical Adirondack forest of maple and spruce.

29. Turin

Cooperators: for 1953, S. S. Sweet; for 1954, Donald Hughes.

This station is at the home of Mr. Sweet, 1,260 feet above sea level. The sampler was mounted 8 feet above the ground in an open hayfield. There were few plants (other than grasses) producing airborne pollen in the immediate vicinity of the sampler.

The large amount of grass pollen recorded is likely due to the surrounding hayfield and low position of the sampler. This may be the reason for the high count for plantain.

30. Watertown

Cooperator: Dale Lawson, who has charge of water purification for Watertown.

This station is at the pumping plant of Watertown Water Works, 500 feet above sea level. The sampler was perched above the roof of one of the buildings using a device that allowed it to be lowered for changing slides. It was 20 feet above the ground and in the open. There were only a few scattered trees nearby that produce airborne pollen: maple, elm, poplar, cedar, willow and oak.

It is possible that some of the pollen recorded as sweet fern is actually birch.

31. Wanakena

Cooperator: James Dubuar, superintendent of State Rangers School.

This station is at the sunshine-transmitter tower near the School, 1,600 feet above sea level. The sampler was mounted on top of the tower, 30 feet above the ground. It was in the open except for three large pine trees on the north side, approximately 10 feet distant. It was in the midst of a pine-spruce forest.

The large amount of pine pollen recorded is probably due, in part at least, to the tall white pine trees close to the sampler. The high count for miscellaneous fungi on April 11 is due to a clump of spores.

32. Saranac Lake

Cooperator: for 1953, Lyall DeLamater, sanitary inspector of Saranac Lake; for 1954, several cooperators assisted in succession, all proving to be unsatisfactory with the exception of Frank Buck, Jr. who took over late in the season.

This station during 1953 was at the Hotel Saranac, 1,580 feet above sea level. The sampler was on the roof of the hotel, some 50 feet above the ground. Unfortunately it was not realized until the end of the season that the sampler was not installed in the place approved. It cleared the parapet by only a few inches rather than the recommended

30 inches and was only 10 feet from construction that would divert normal air currents. The sampler was moved to the roof of the Paul Smith Building for 1954. This was an excellent location but poor co-operation resulted in a discontinuous record. The forested hills at this station are mostly maple and birch with pine and some spruce.

Some of the counts for birch pollen were too large to show on the graph; May 9: 3,171 grains, May 10: 55, May 11: 888 and May 12: 463. This station had the highest total count for birch, being more than twice the next highest (Indian Lake). It also led with fir, spruce, hemlock and maple. It was surpassed only by Belle Ayre Mountain for beech and only by Newburgh for ash. The sum total for all pollen grains was higher than at any other station. The ragweed count was higher than would be expected at Saranac Lake and may not well reflect the situation at the lower levels. Large amounts of algae were found on the slides, probably due to the position of the sampler.

33. Dannemora

Cooperator: Warden J. V. Jackson, Clinton Prison. The slides were changed by Woodbury Wallace, assisted by Charles Stewart.

This station is at the prison, 1,400 feet above sea level. The sampler was 35 feet above the ground on the roof parapet of the Administration Building. Plants producing airborne pollen in the immediate vicinity are the street trees: maple, elm and birch. The surrounding woods are of maple, ash, beech, birch and poplar, with spruce and some pine at the higher levels.

34. St. Regis Falls

Cooperator: Arthur Fadden.

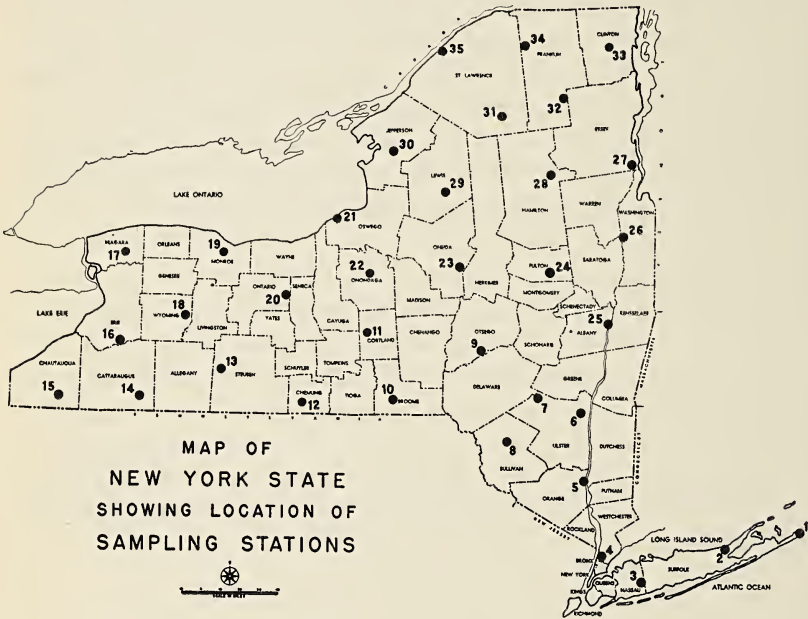
This station is 1,300 feet above sea level with the sampler about 40 feet above the ground on the flat roof of the school building, in the open. Plants producing airborne pollen in the general vicinity are: maple, elm, pine, willow, poplar and larch. There is some ragweed and plantain in the schoolyard. Woods one-fourth mile west of the station are mostly maple.

35. Ogdensburg

Cooperator: Dr. George F. Etling, director, St. Lawrence State Hospital. The slides were changed by Mrs. Anna Martin.

This station is at the Hospital, 250 feet above sea level. The sampler was mounted on the roof parapet, approximately 25 feet above the ground. It was in the open with nothing to divert air currents except a higher portion of the building 40 feet south of the sampler position.

Plants producing airborne pollen in the vicinity are planted trees: poplar, maple, elm, oak, spruce and pine. Woods to the south are mostly maple. There are hayfields on the south and west.

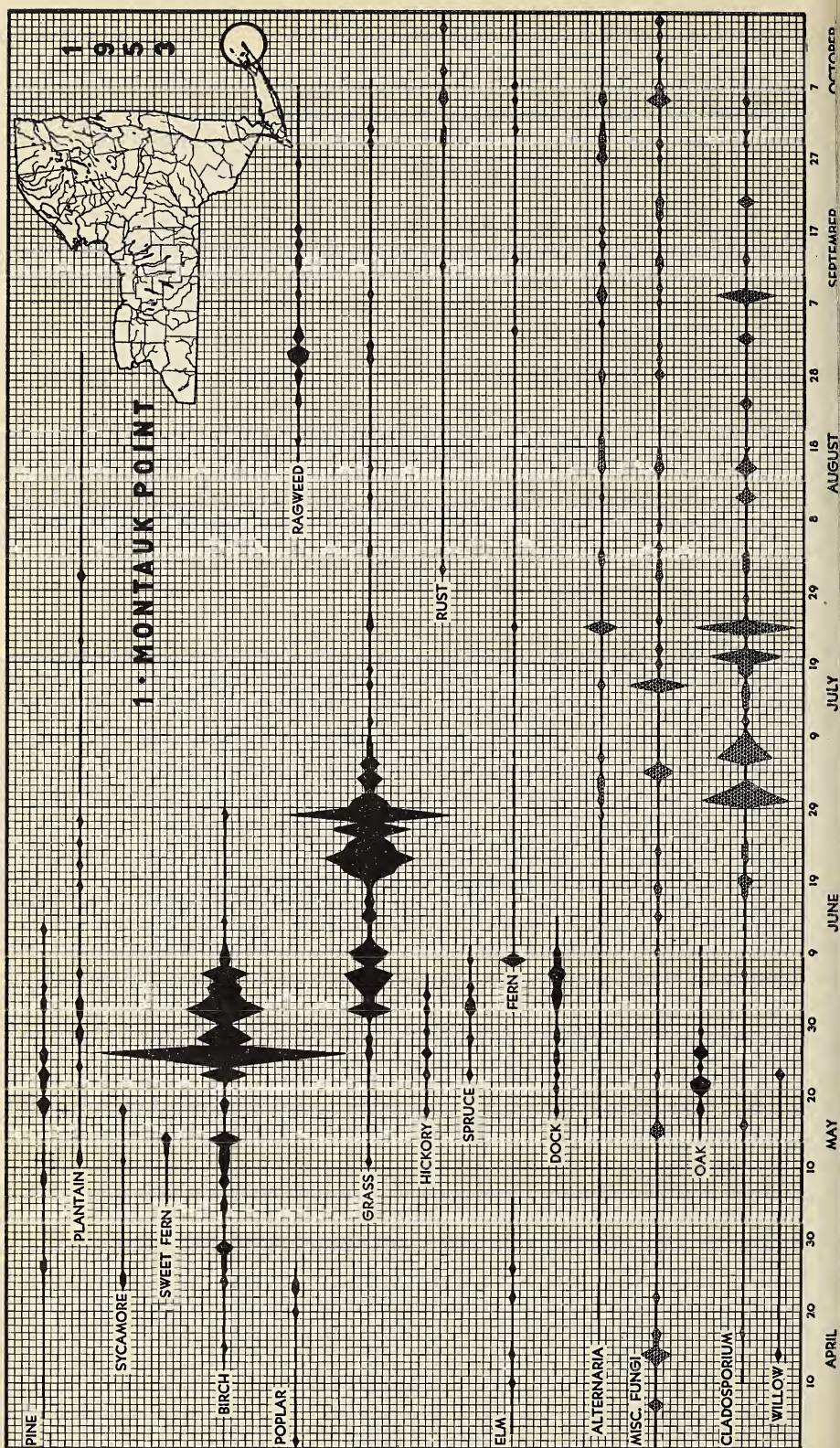


EXPLANATION OF GRAPHS

The following graphs present some of the data from the samples taken during 1953 at 36 stations in 35 localities. Pollen grains and fern spores are shown in solid black; fungus spores are indicated by a pattern. Each tiny square (vertically) represents five (5) granules per square centimeter of slide surface exposed for a 24-hour period. A solid line indicates that the average daily count was one or zero. A broken line indicates more than one week of consecutive counts of zero. Extremely high points may be due to clumped particles; where this is so, specific mention is made in the discussion of the graph. Multiple peaks may be due to different flowering dates of species in the genus or to fluctuations in the weather. The circle on the map has a 25-mile radius.

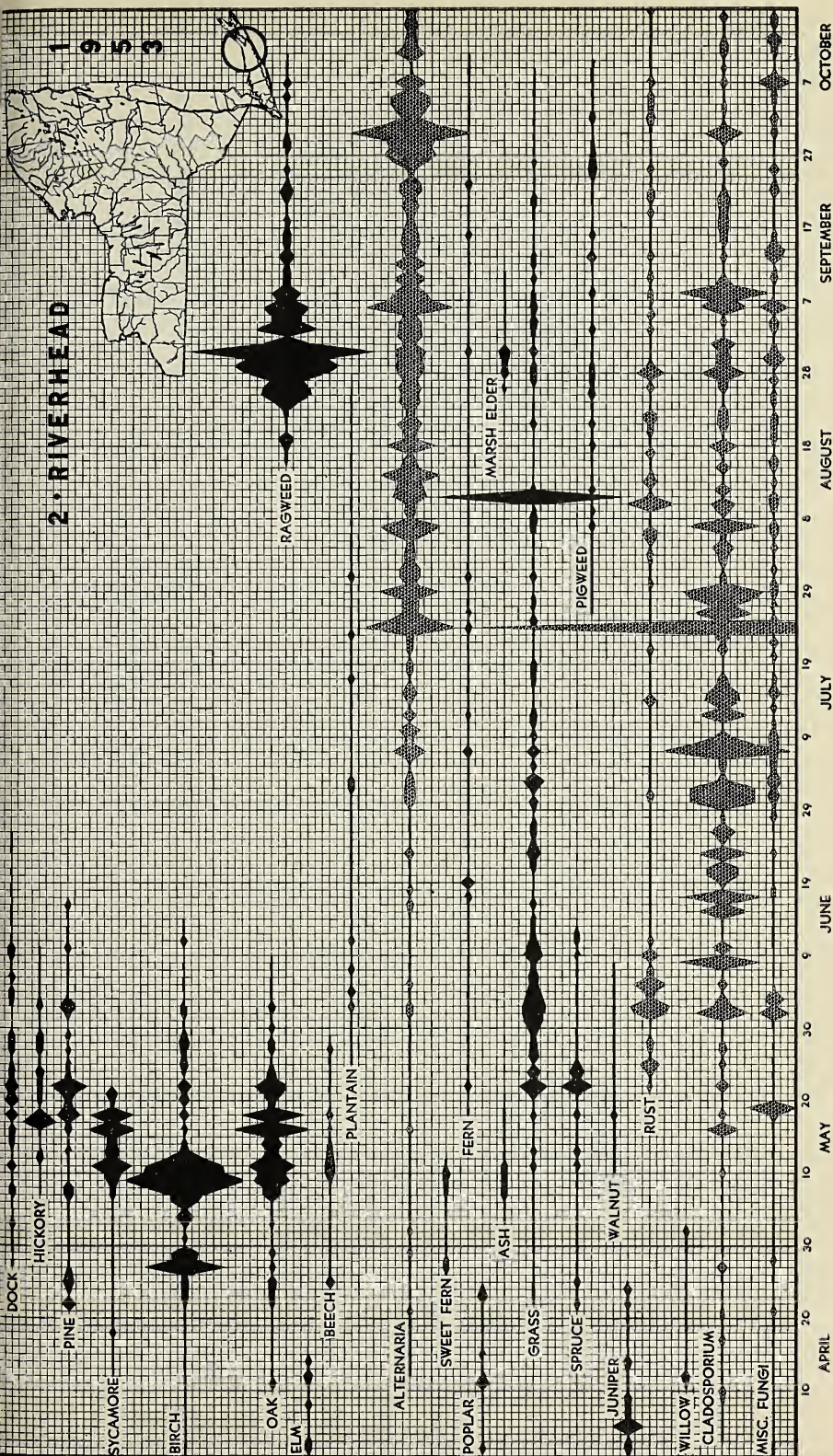
Only those pollen grains and fungus spores for which the total count for the 200-day period was 15 or more are shown, unless there was an individual day's count of 5 or higher.

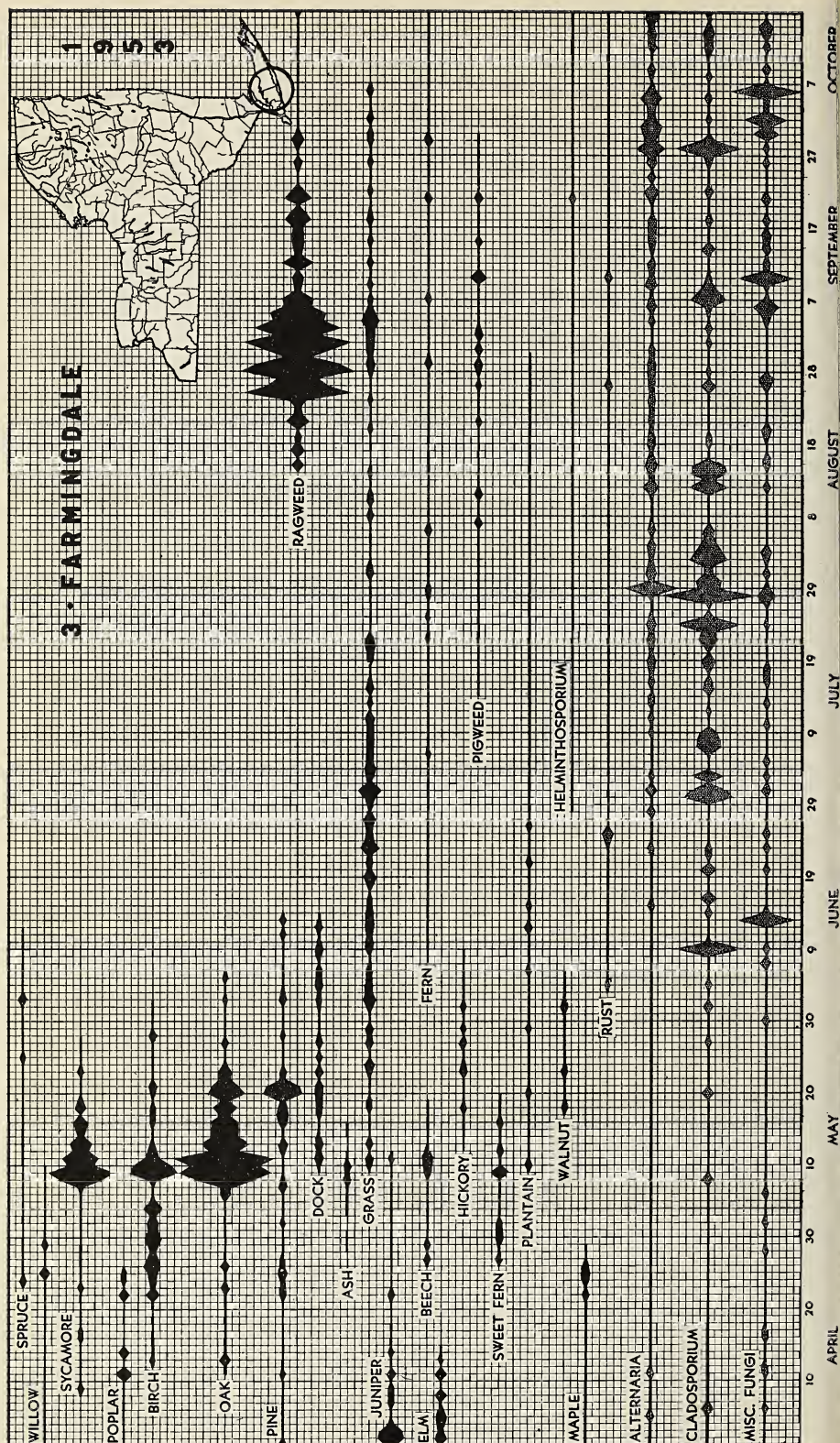
It should be emphasized that the graphs indicate for any entity the average number of particles caught on a square centimeter of greased surface and do not directly indicate the average number per unit volume of air. Factors for converting greased slide data to a volumetric basis vary greatly with different plants and also vary with different conditions of weather and with different concentrations of particles. Thus, birch and pine may not be compared to the same degree that birch may be compared between stations. The graphs show what kinds of particles were in the air and their relative abundance at different times during the growing season of 1953. It must be kept in mind that other years would furnish somewhat different data and it is with some hesitancy that the 1953 information is presented before the 1954 data are available for comparison. To indicate what variation may be expected, data obtained at the Albany stations for 1954 and 1955 are included. It should be realized that these data for 1953 may only be used to describe the situation for following years in much the same way that weather data for one year may be used to indicate weather in the future. As an indication of the yearly variation, compare the Albany graphs (Nos. 25 and 25A) for 1953, 1954 and 1955.



2. RIVERHEAD

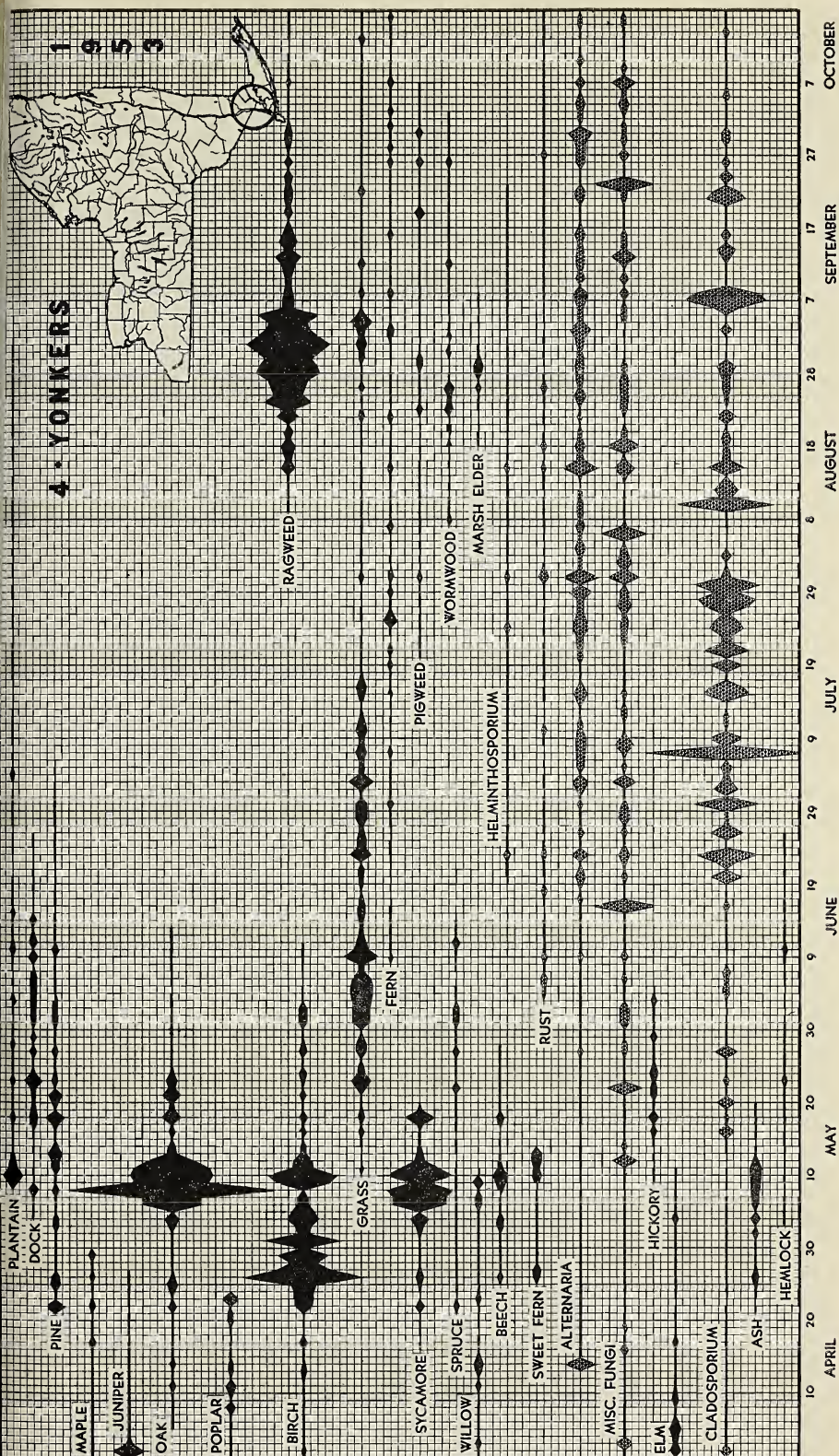
1953

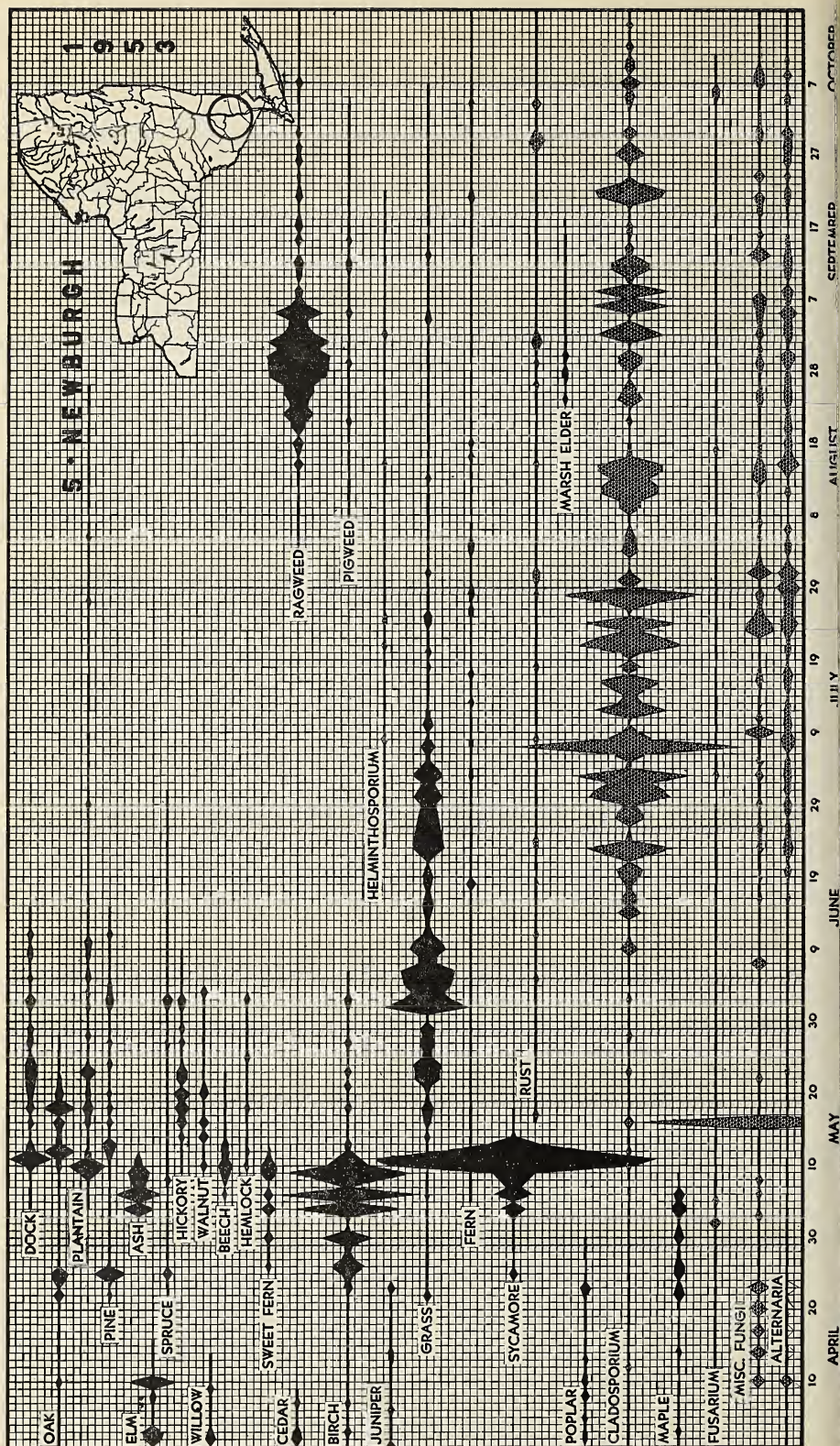


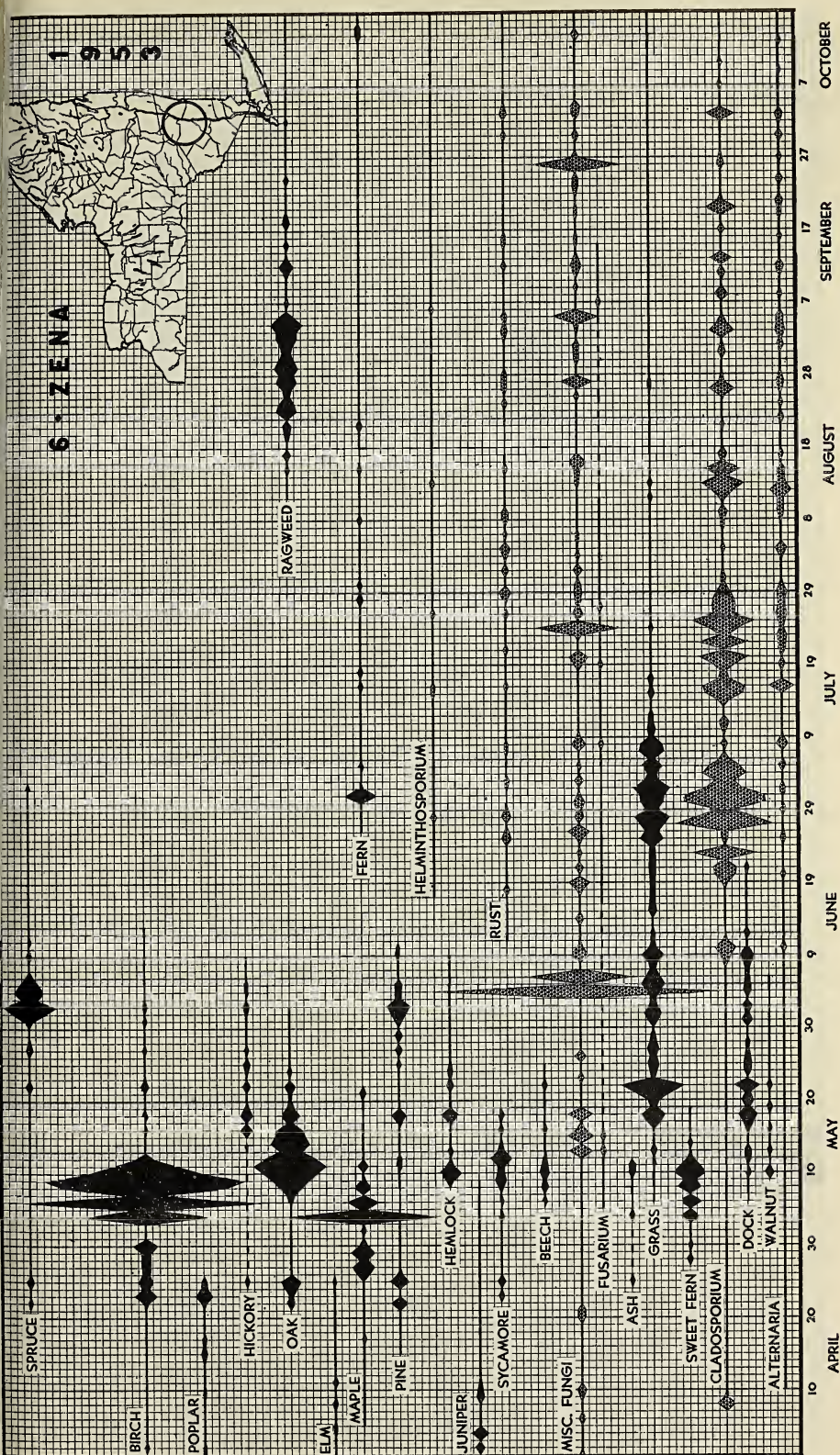


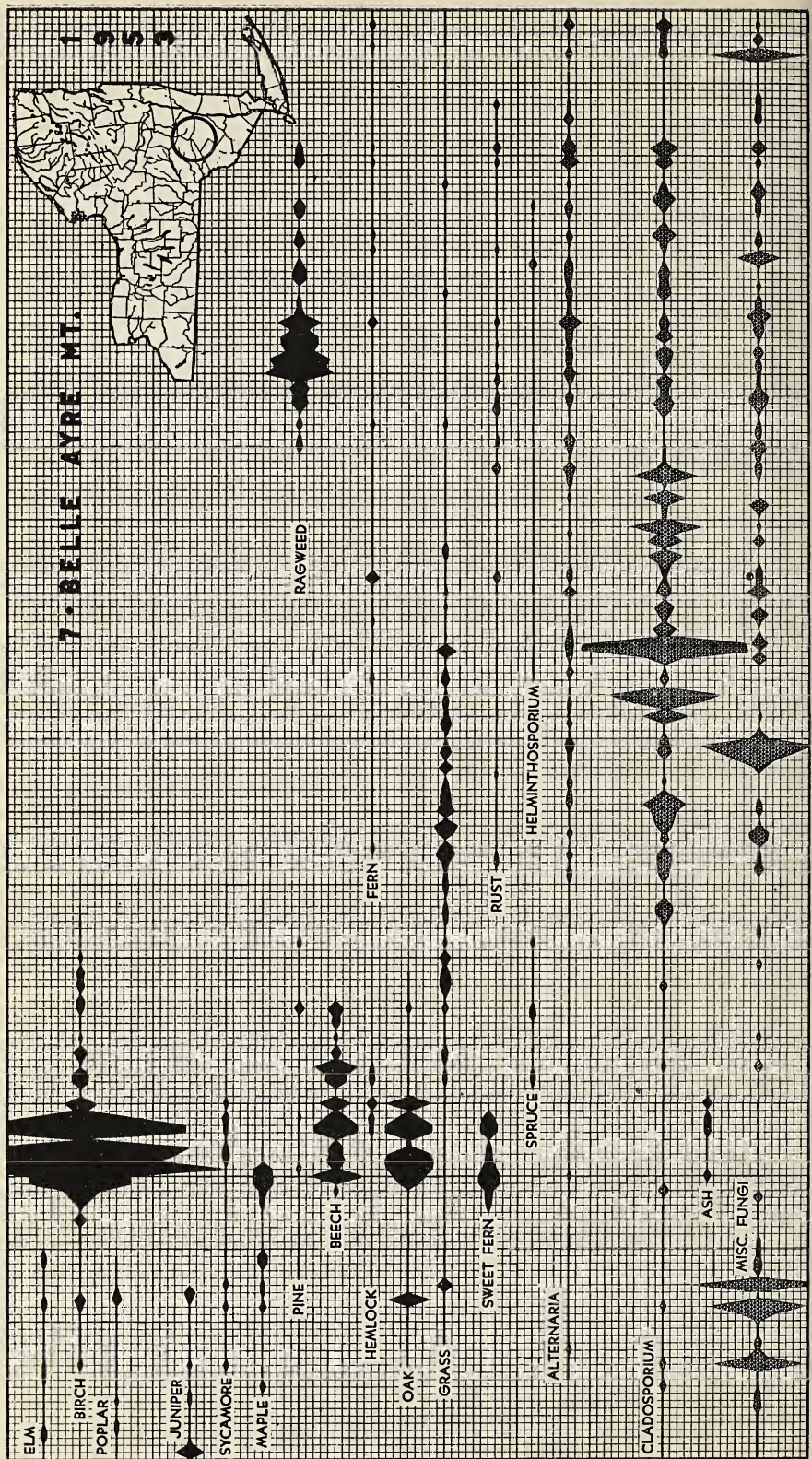
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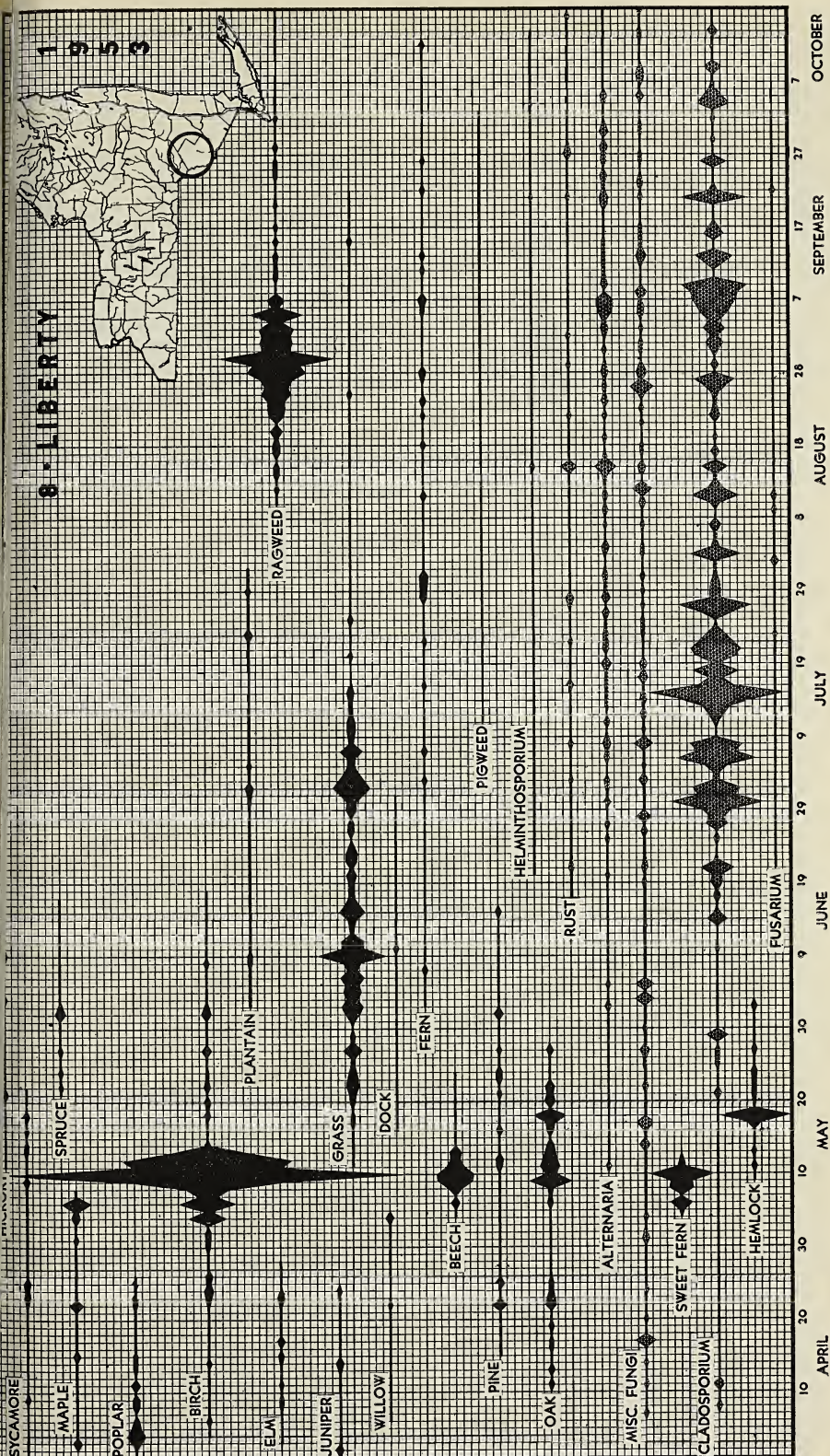
1953

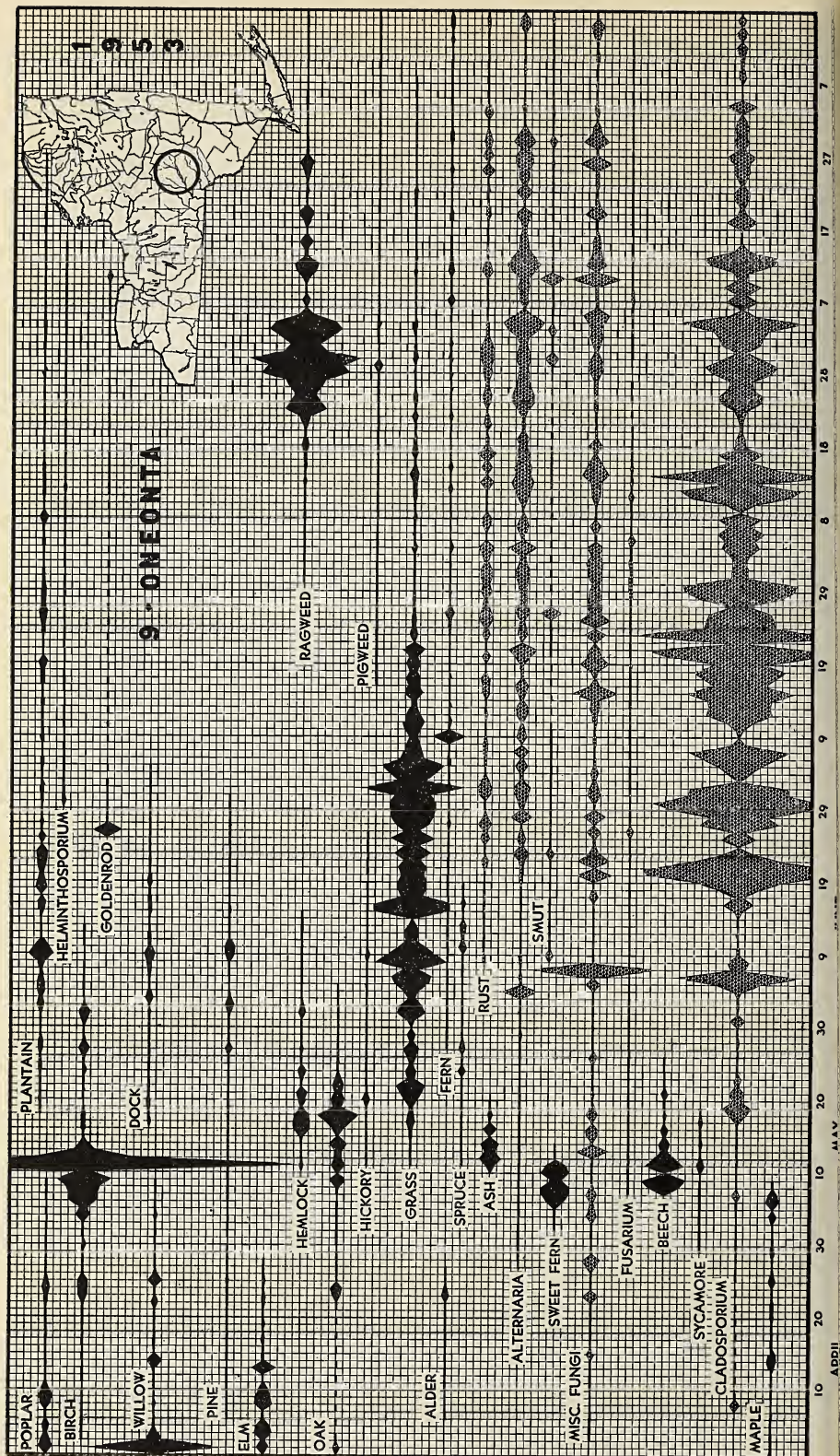




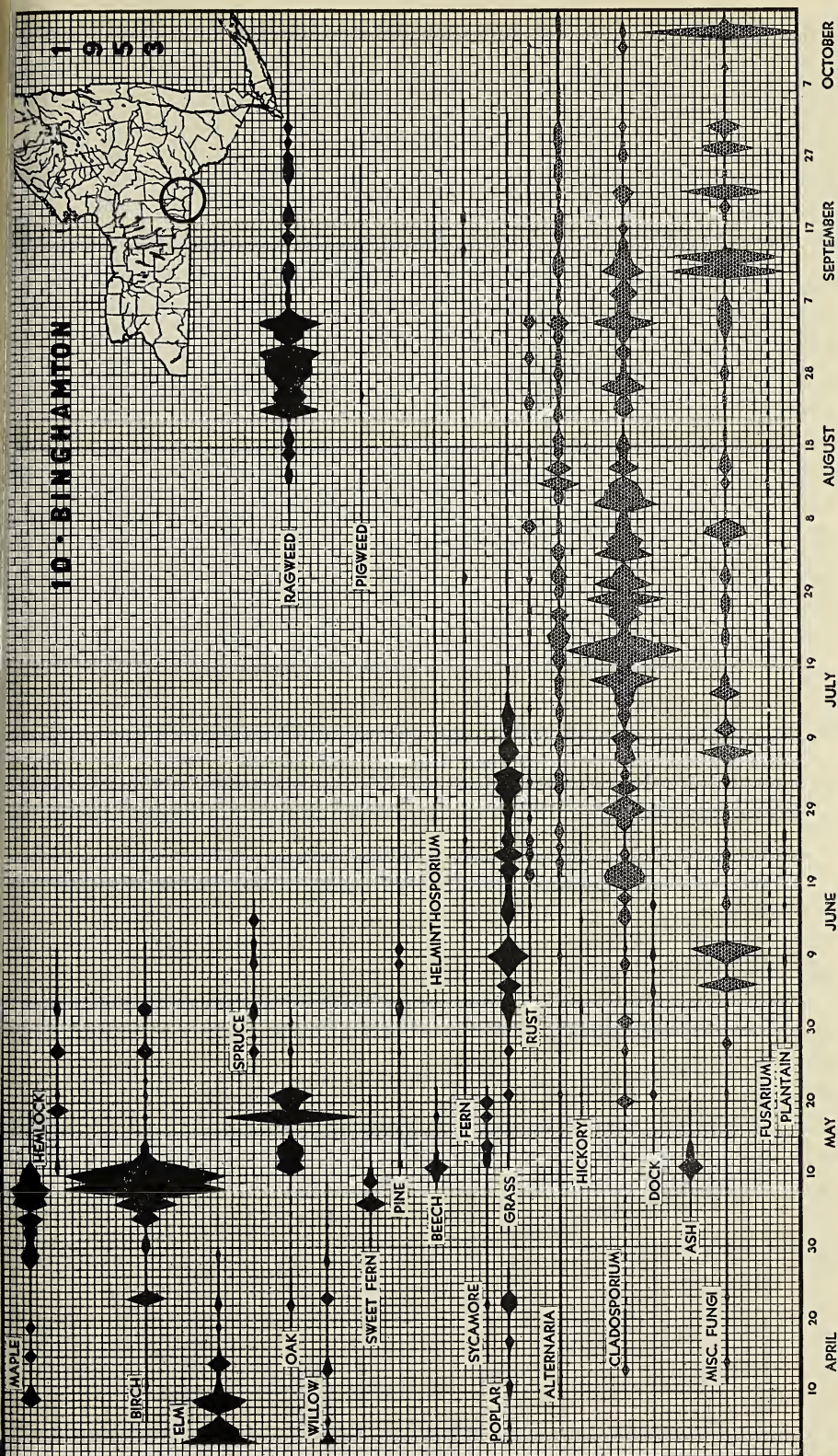


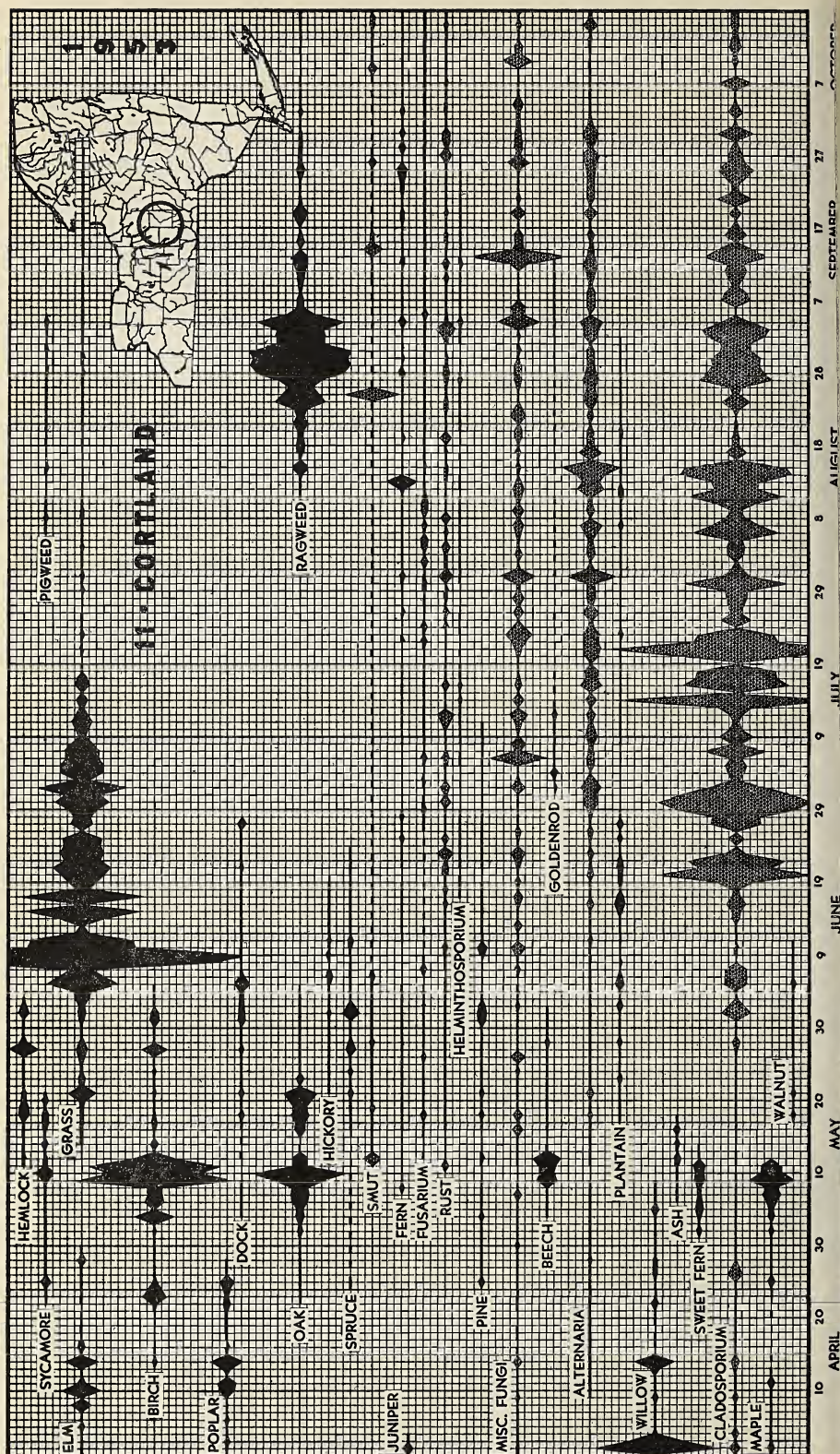


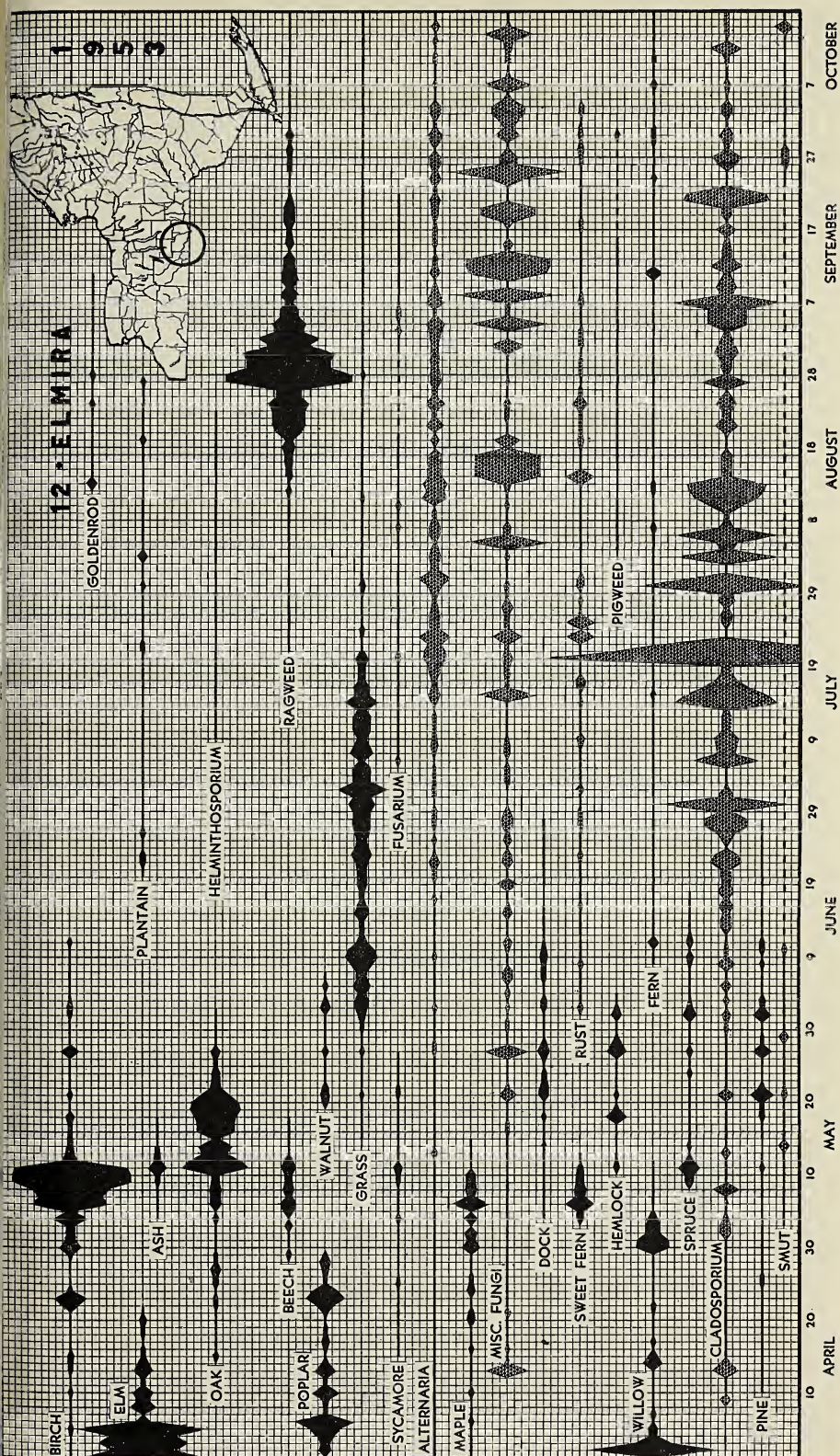


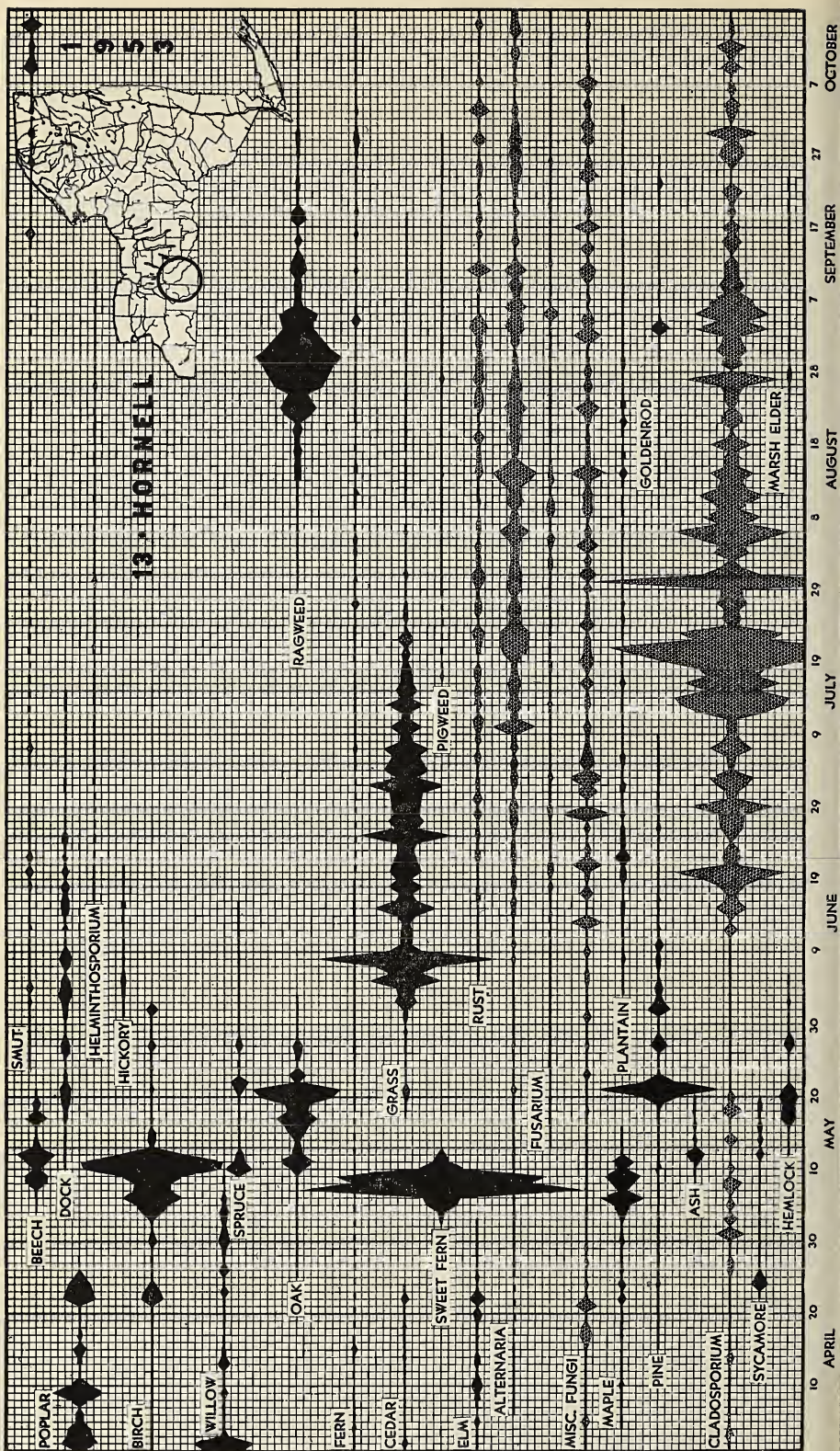


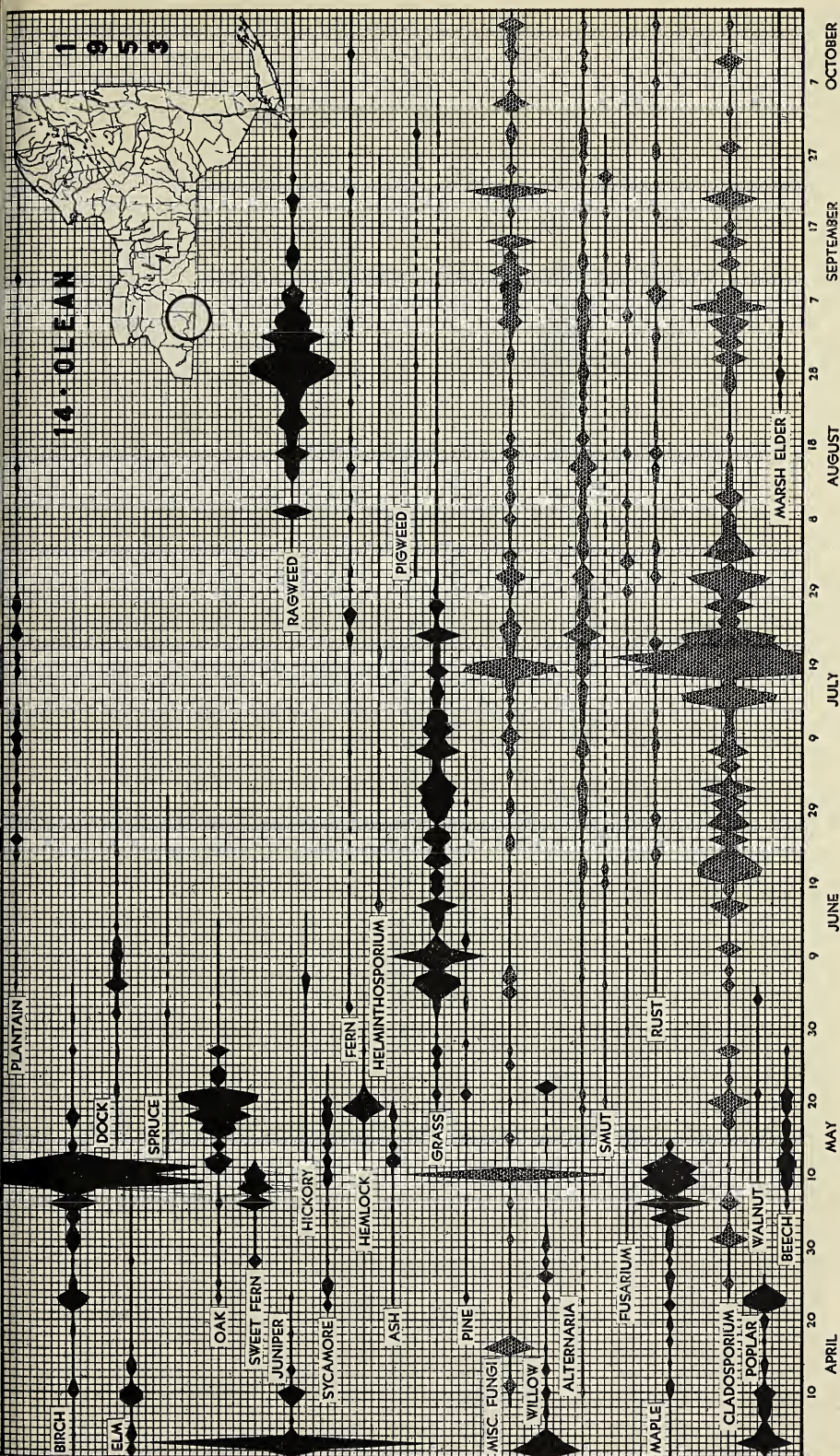
10 - BINGHAMTON

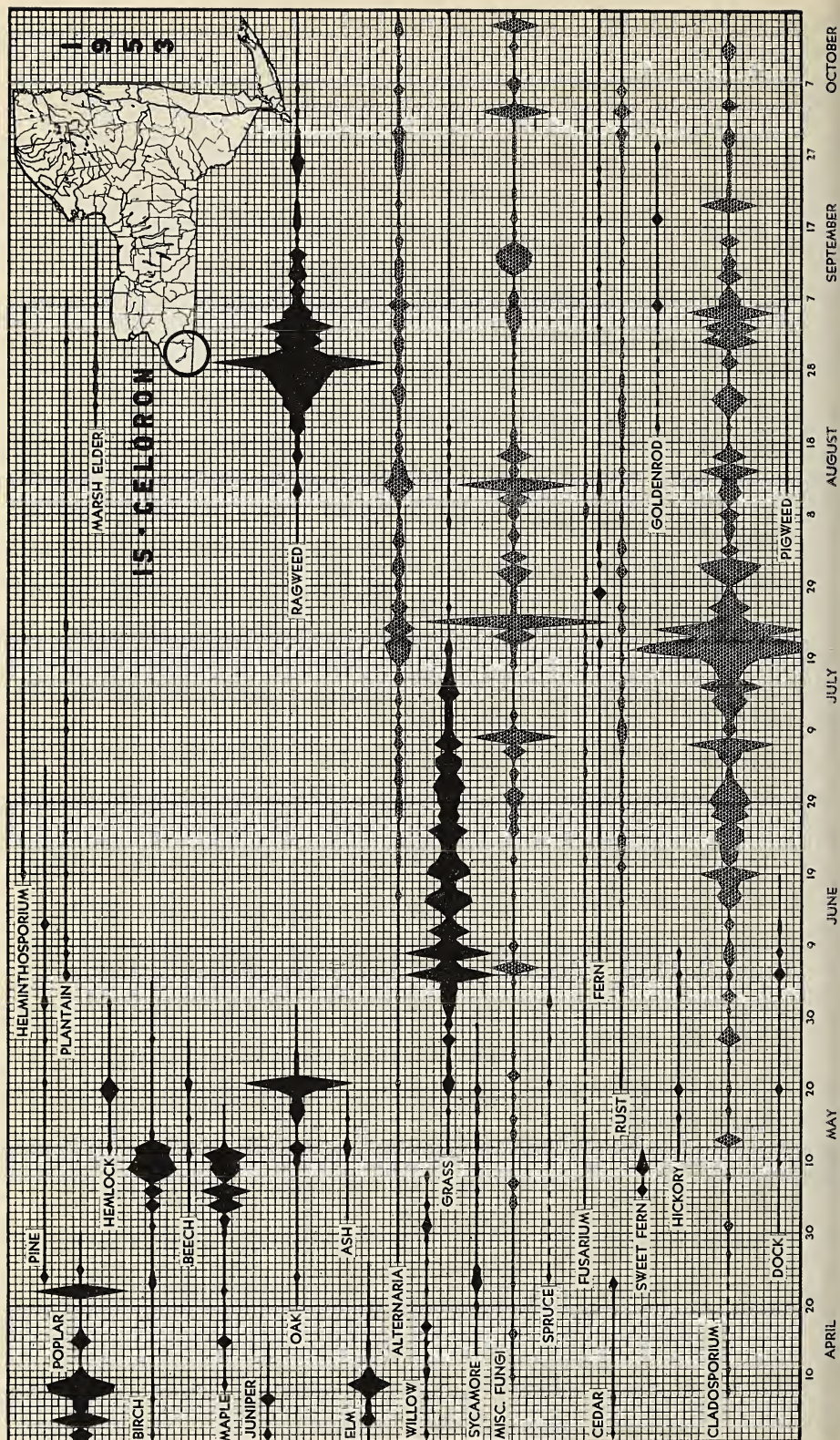


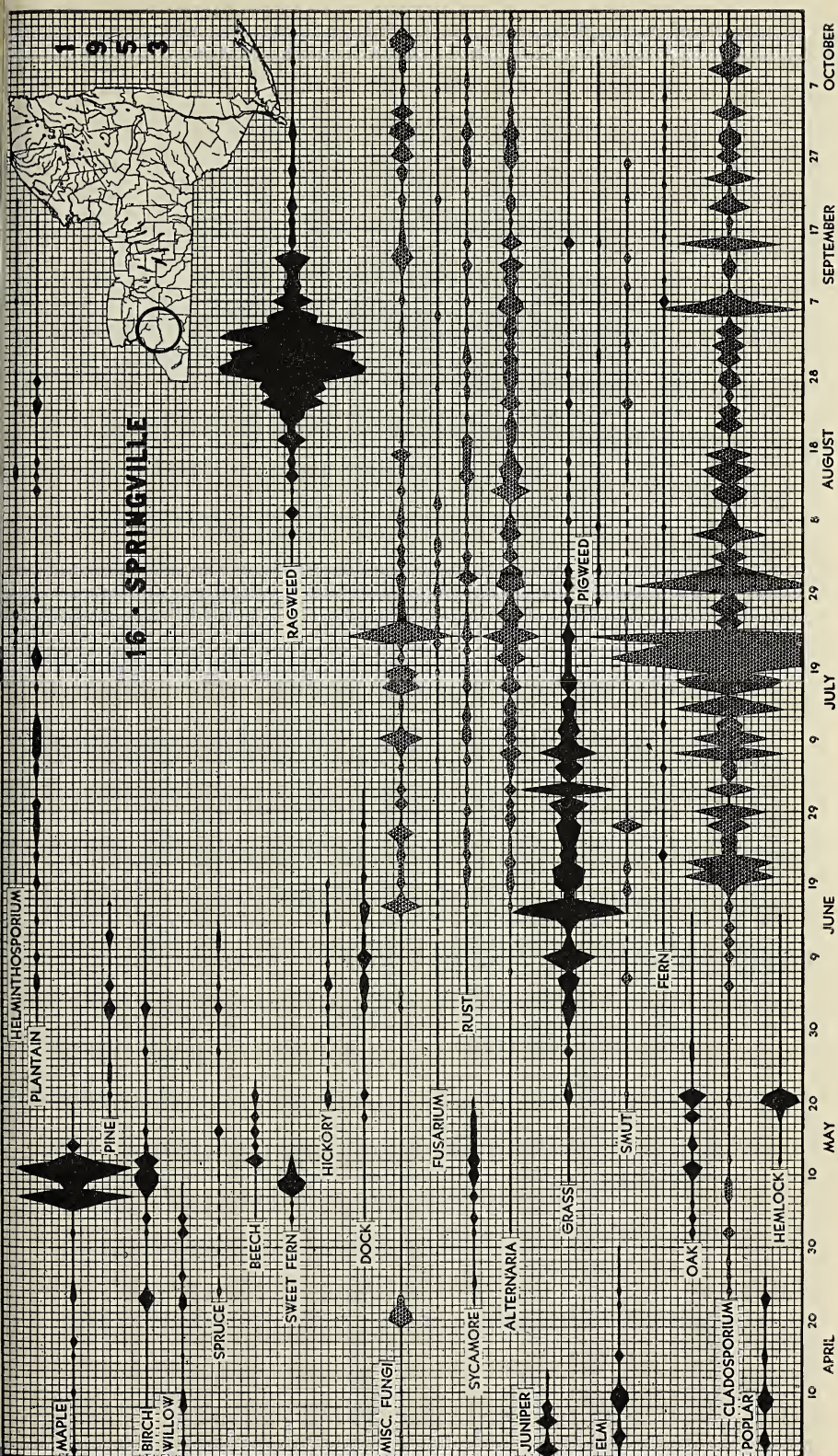


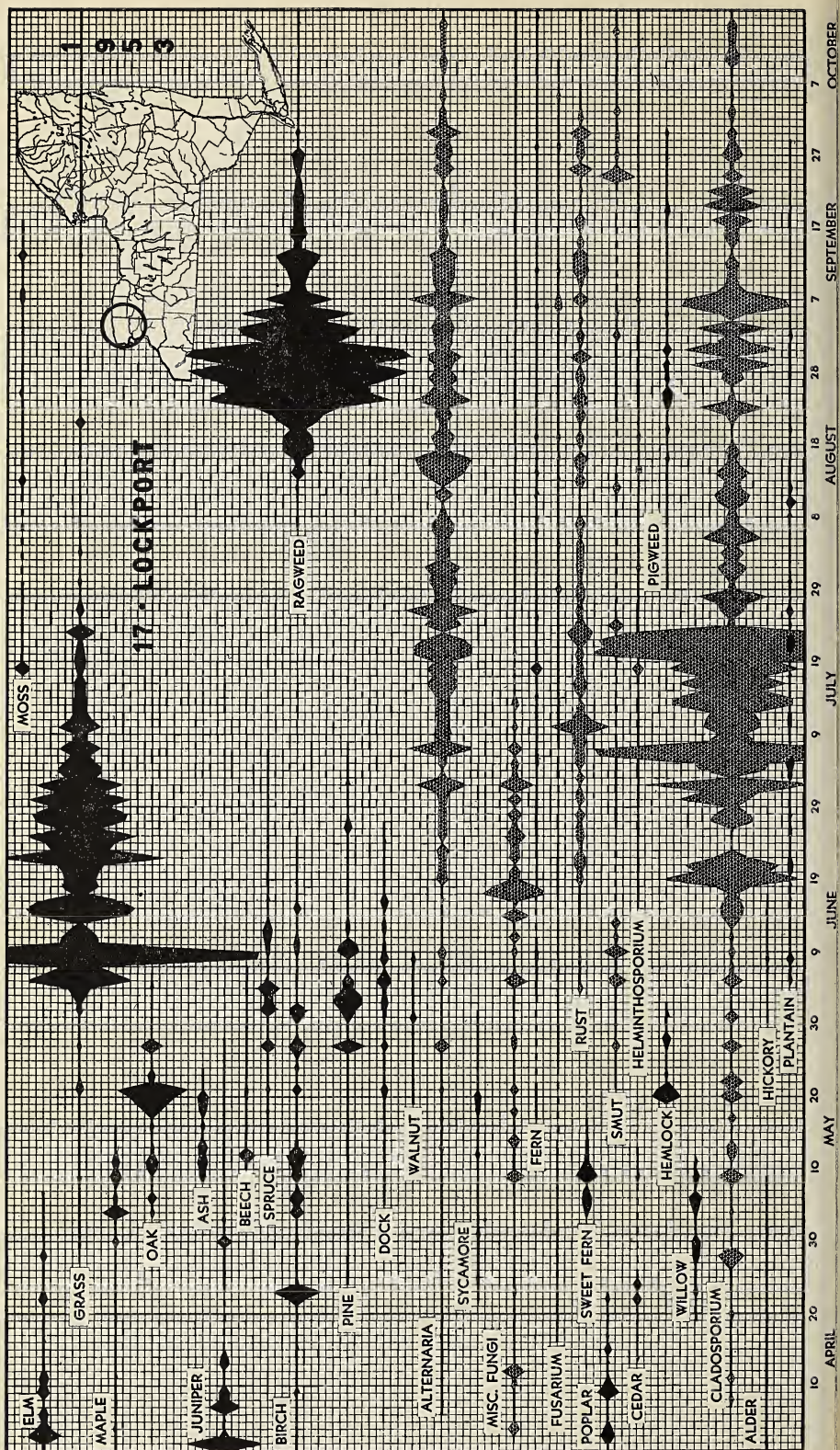


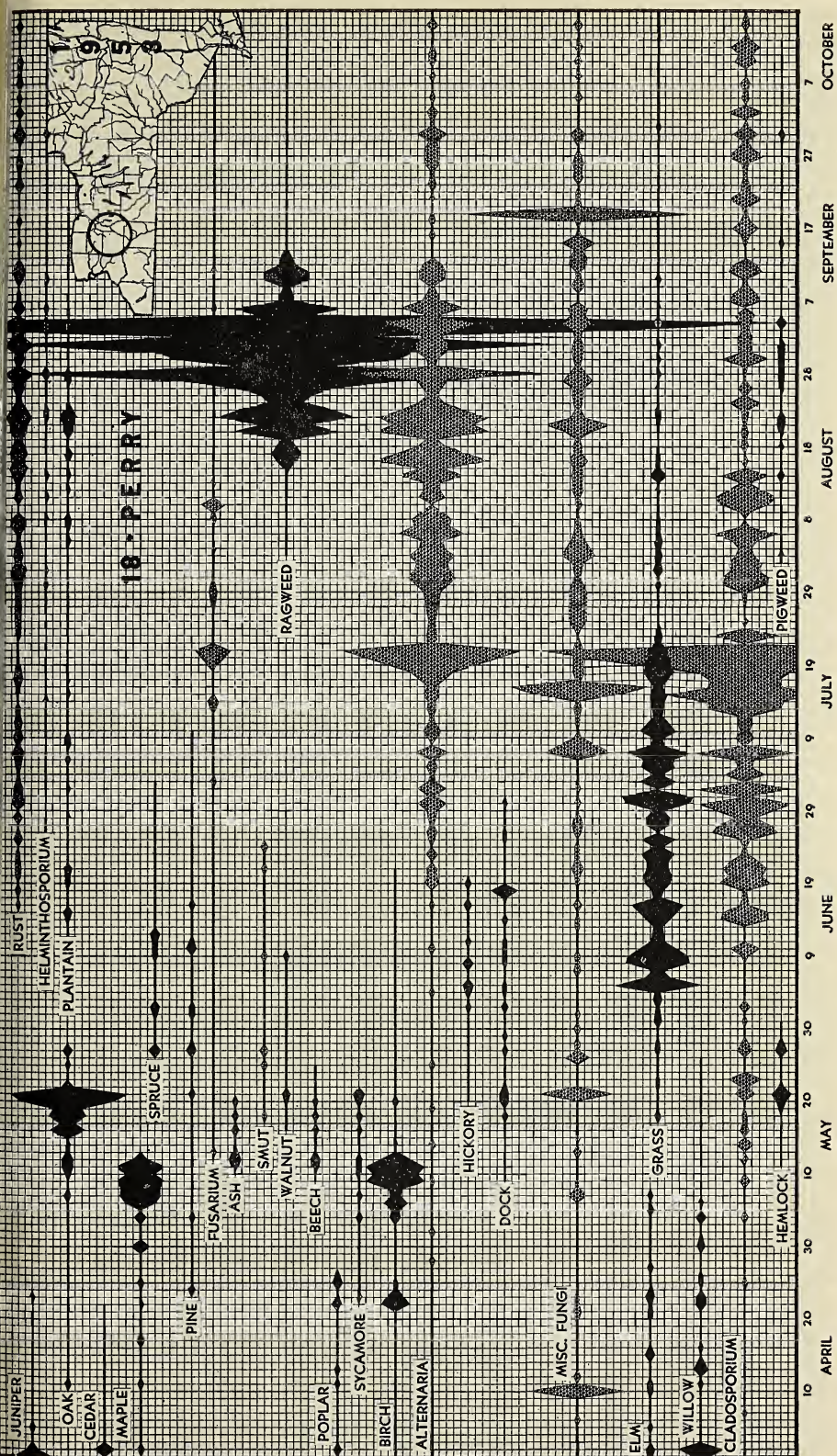


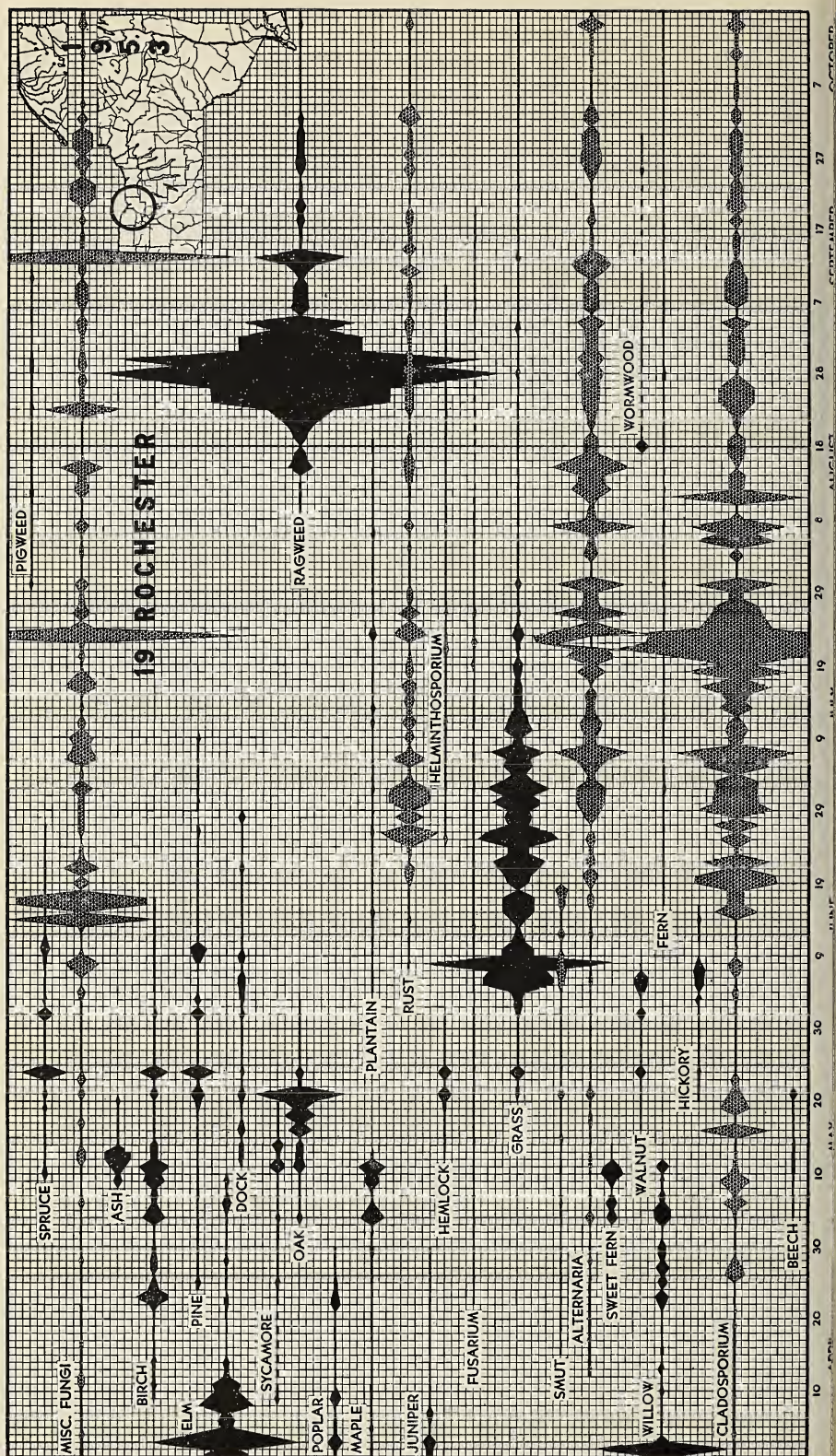


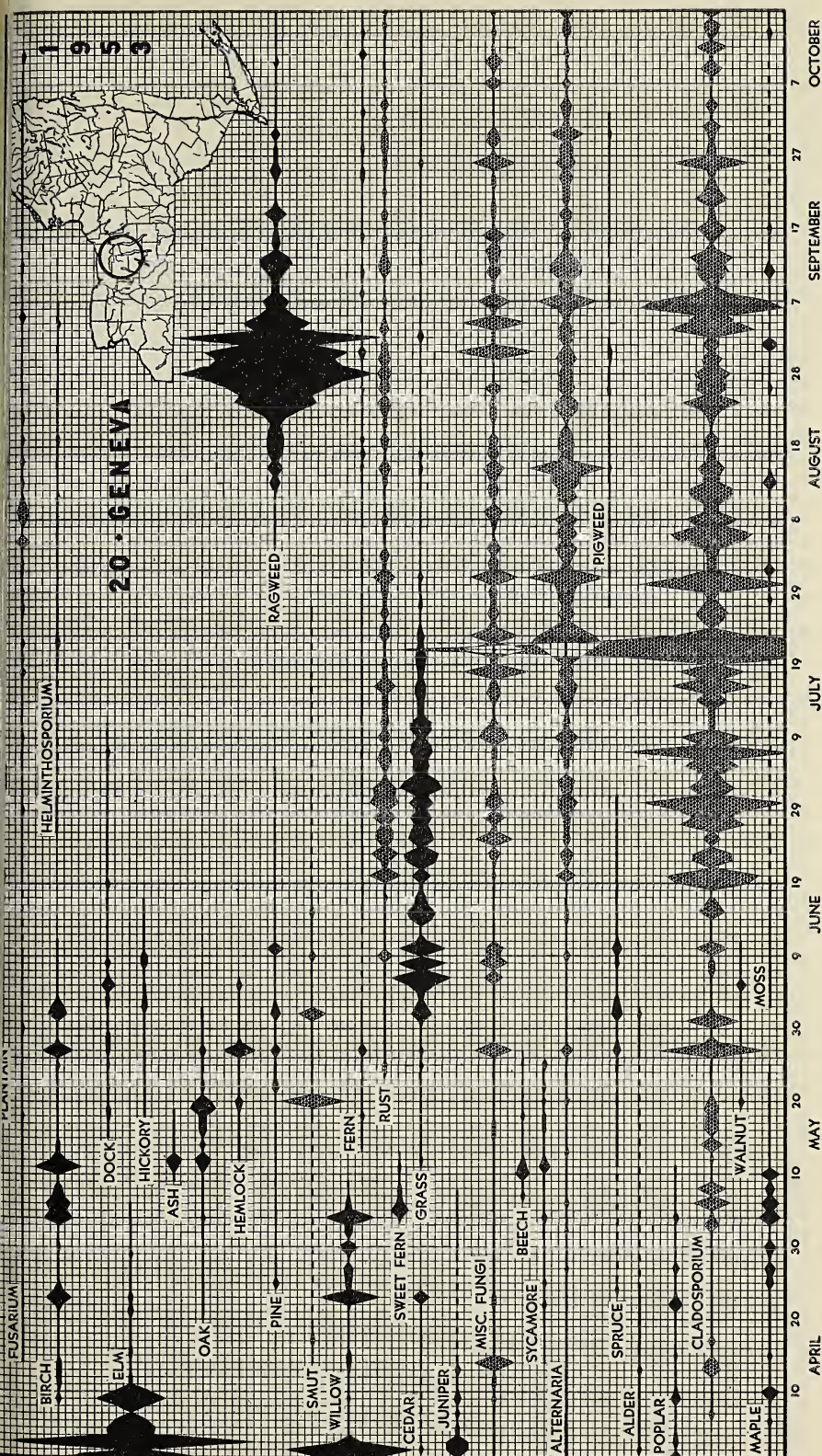


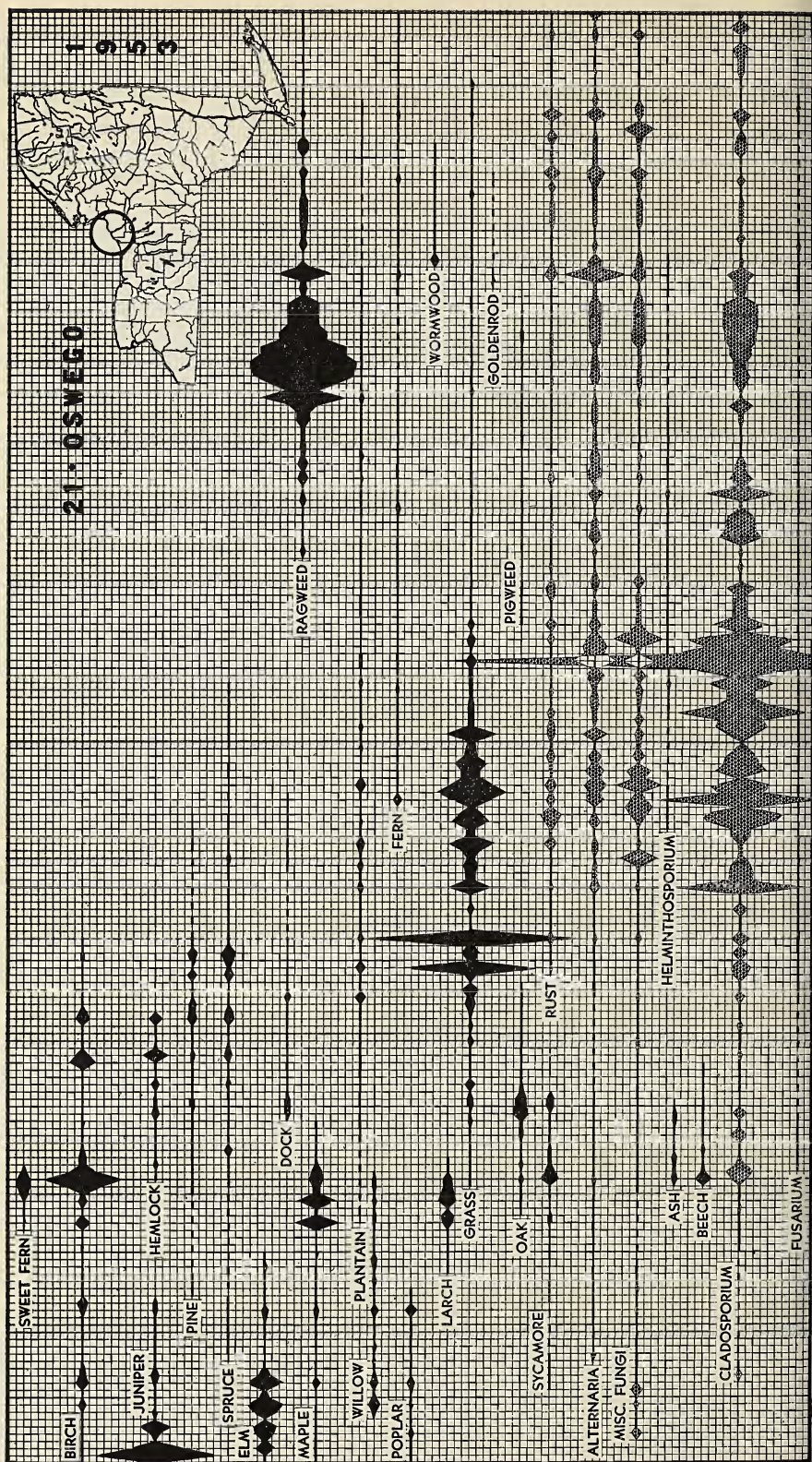






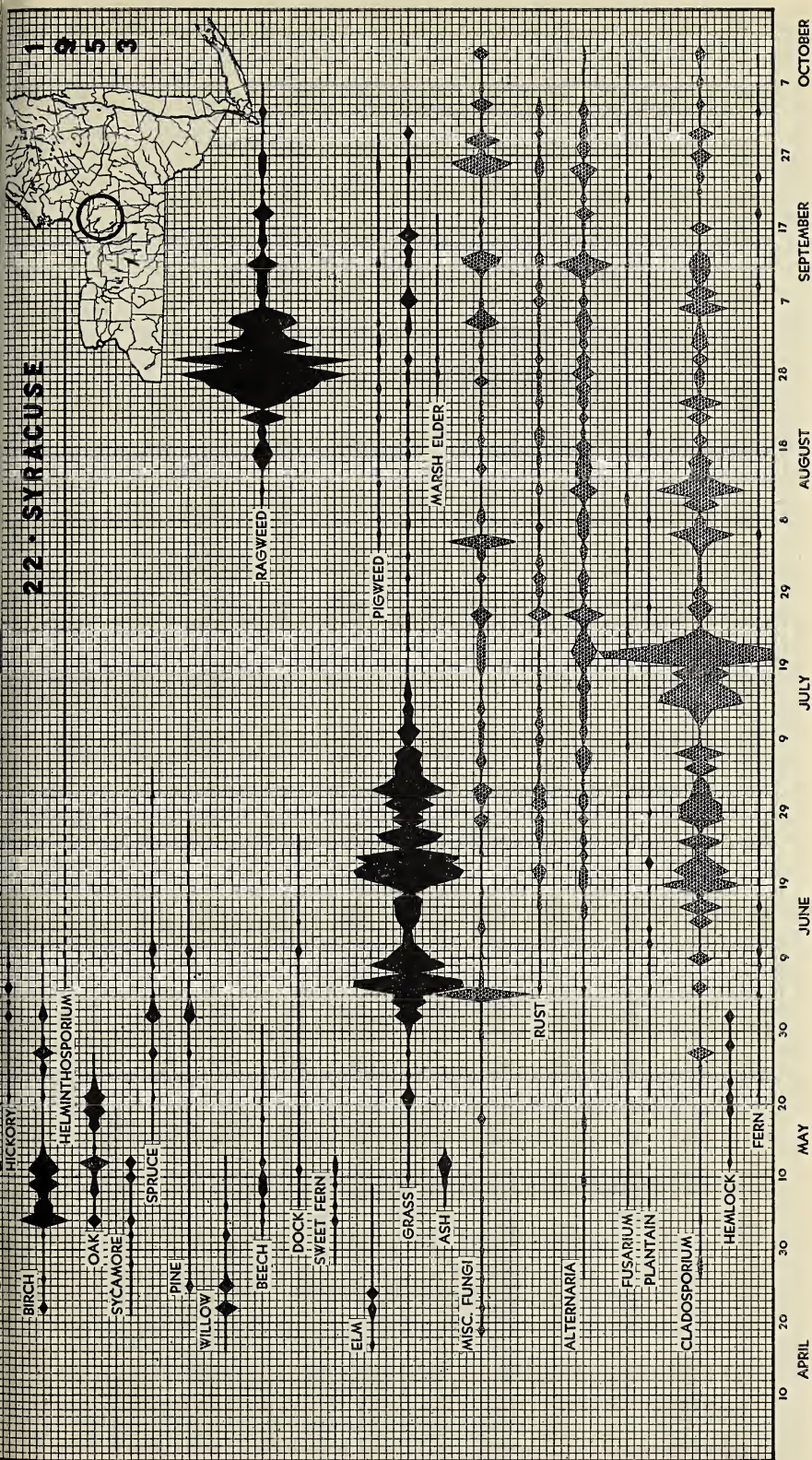


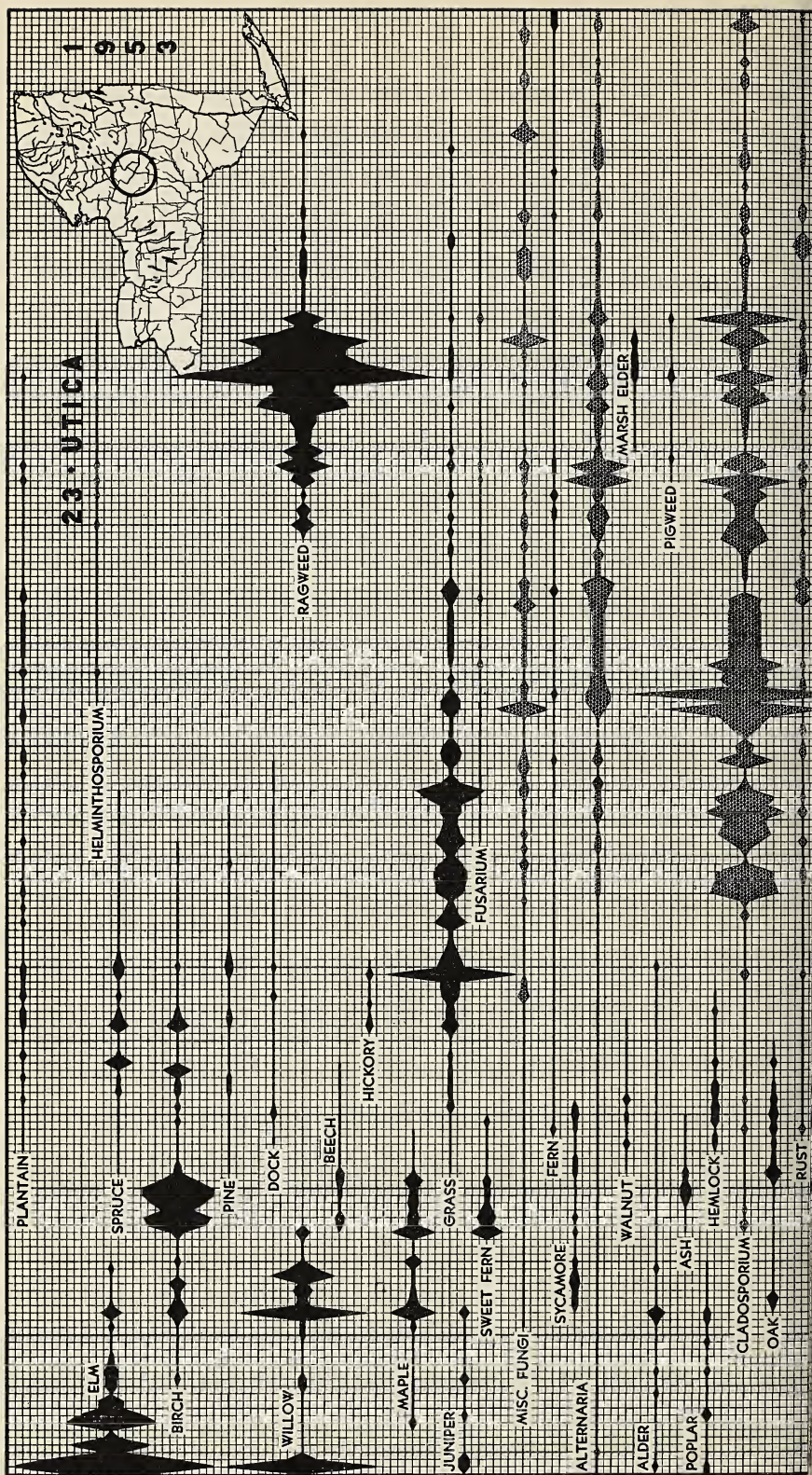


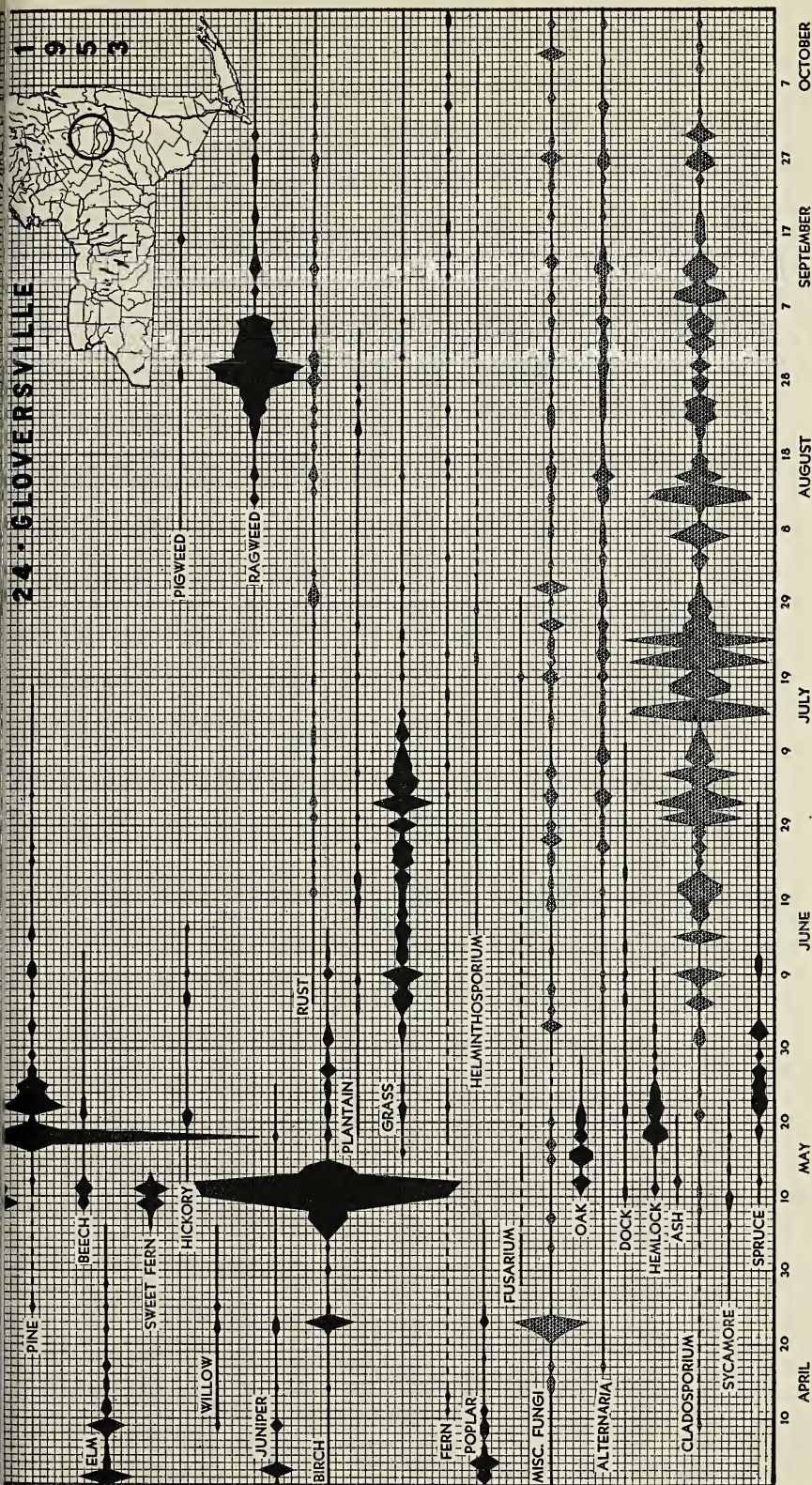


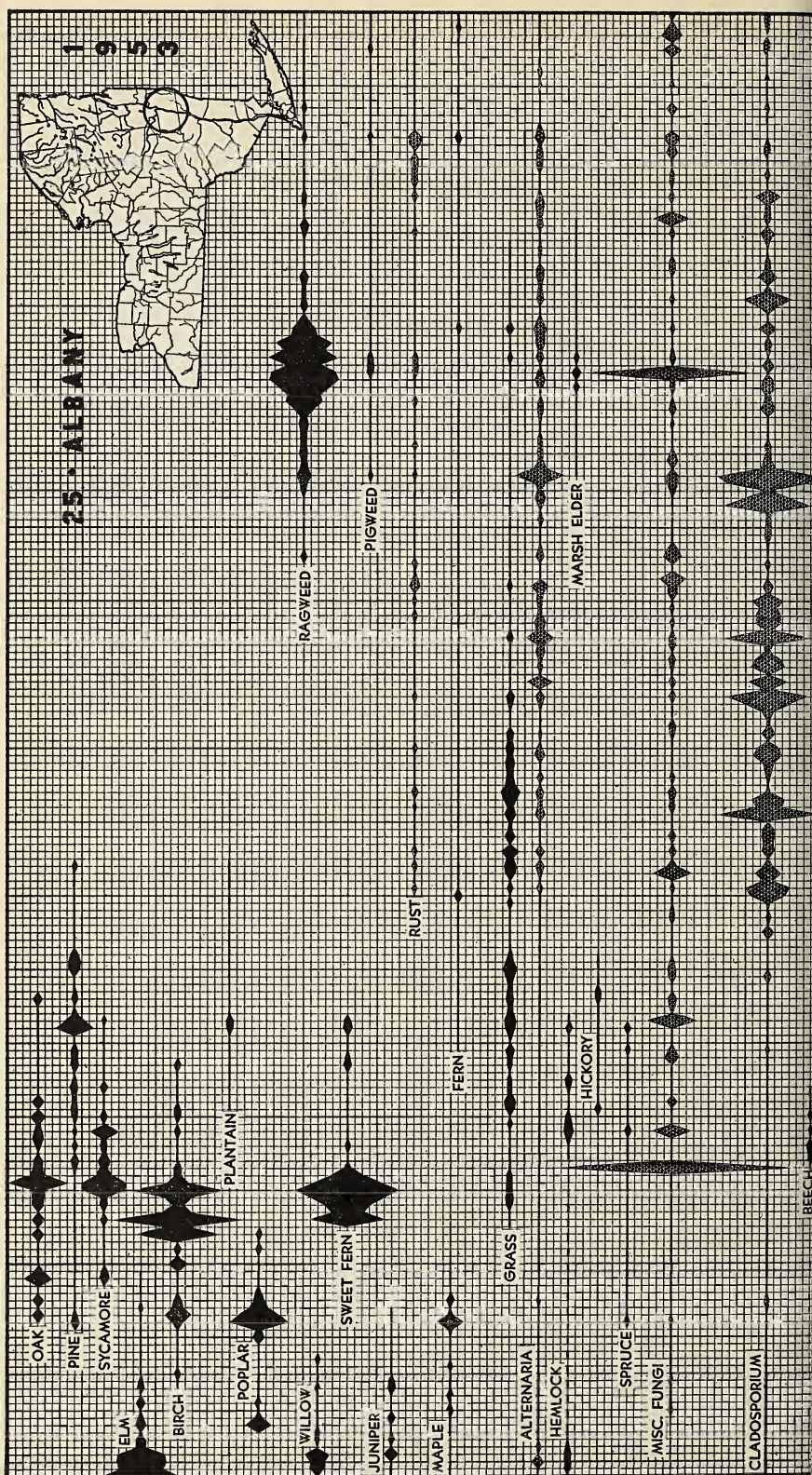
22 - SYRACUSE

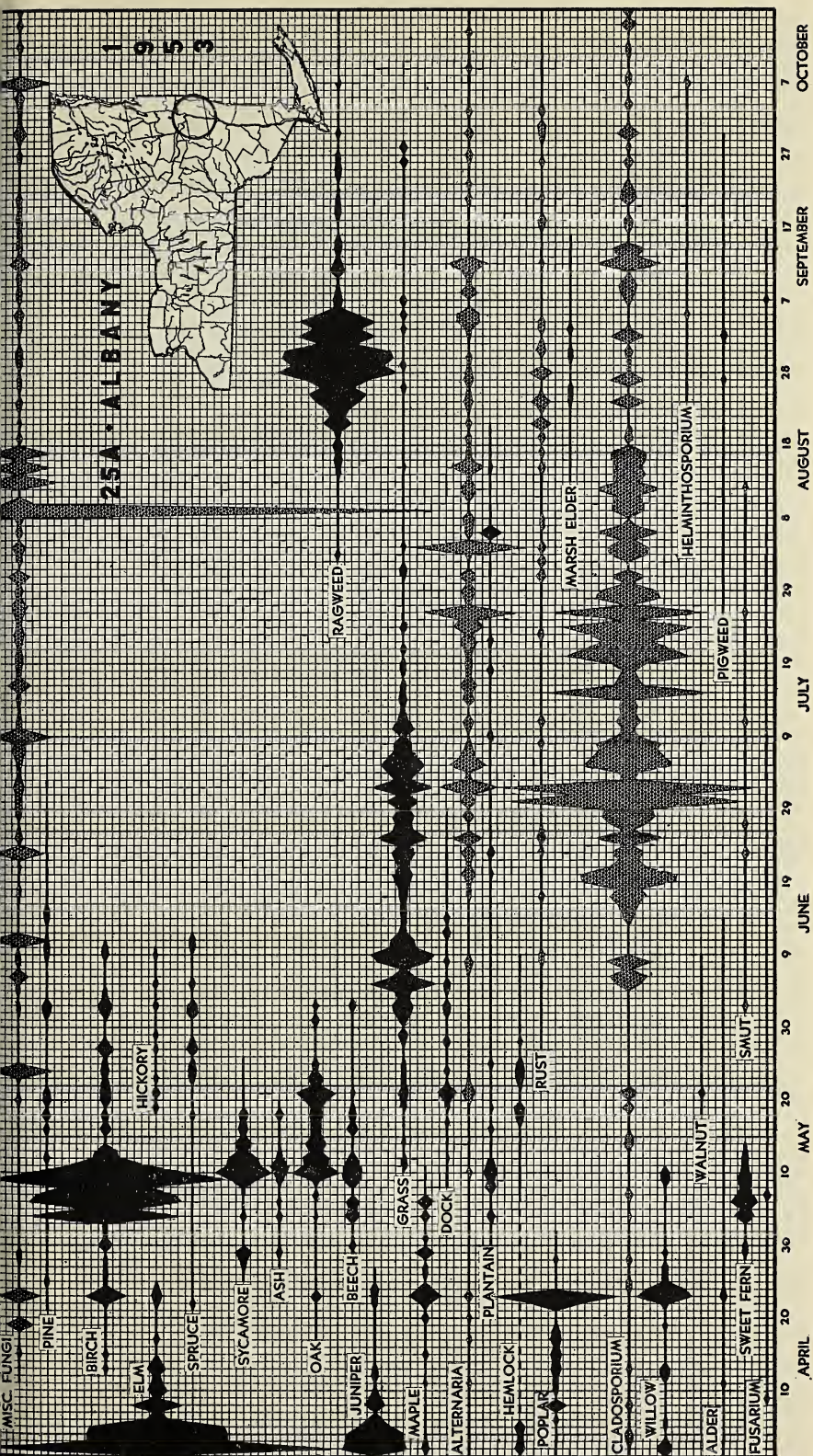
1953



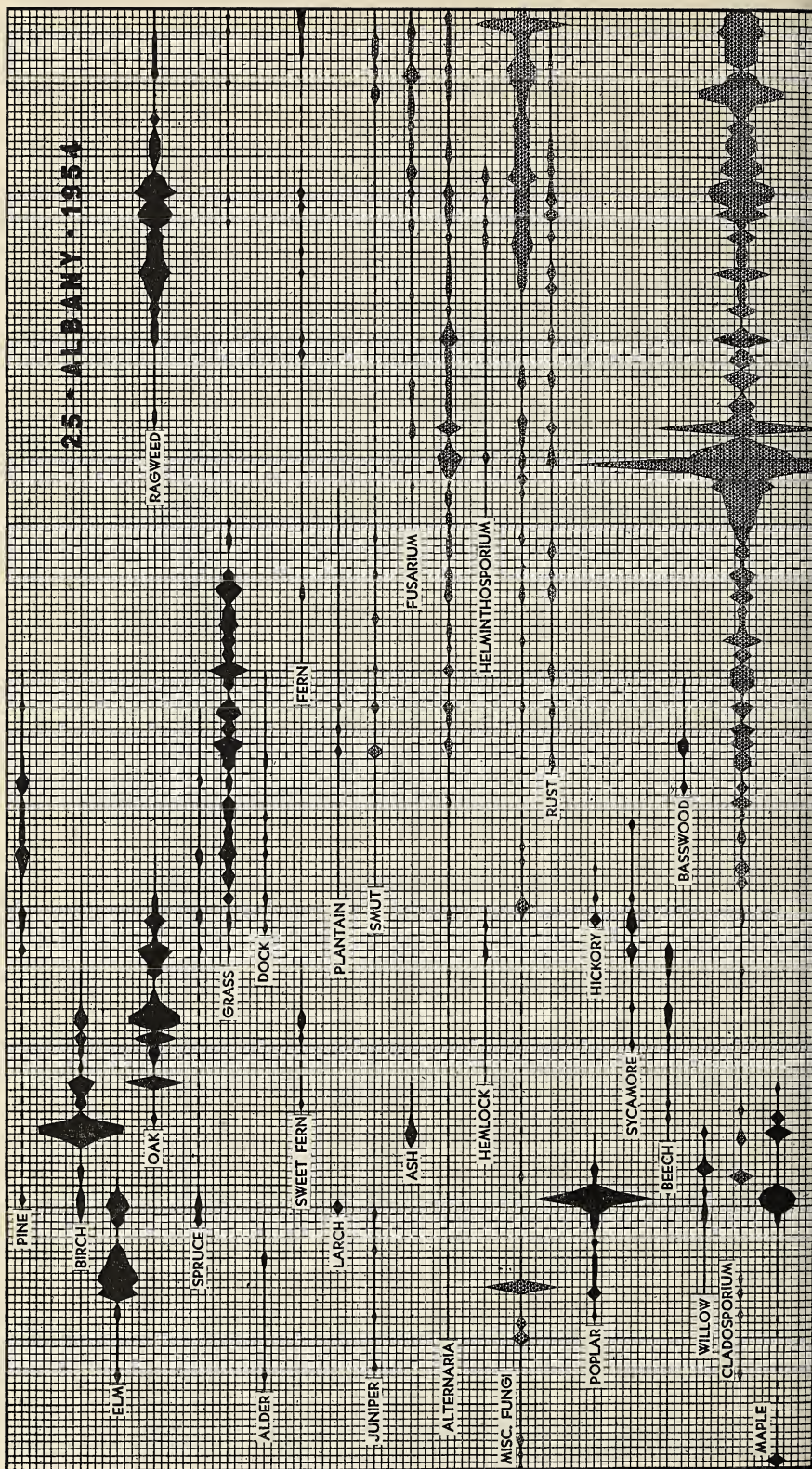




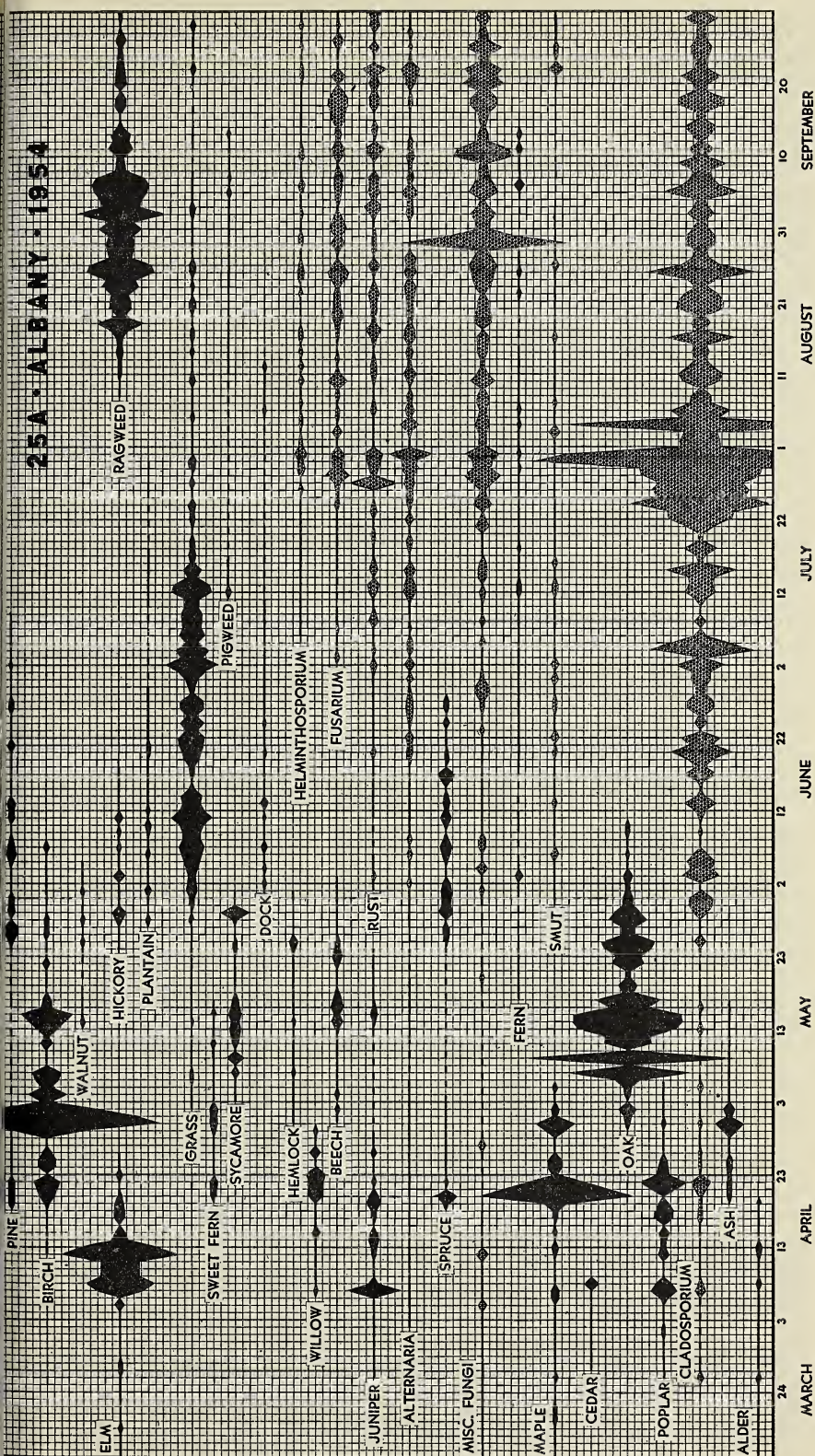




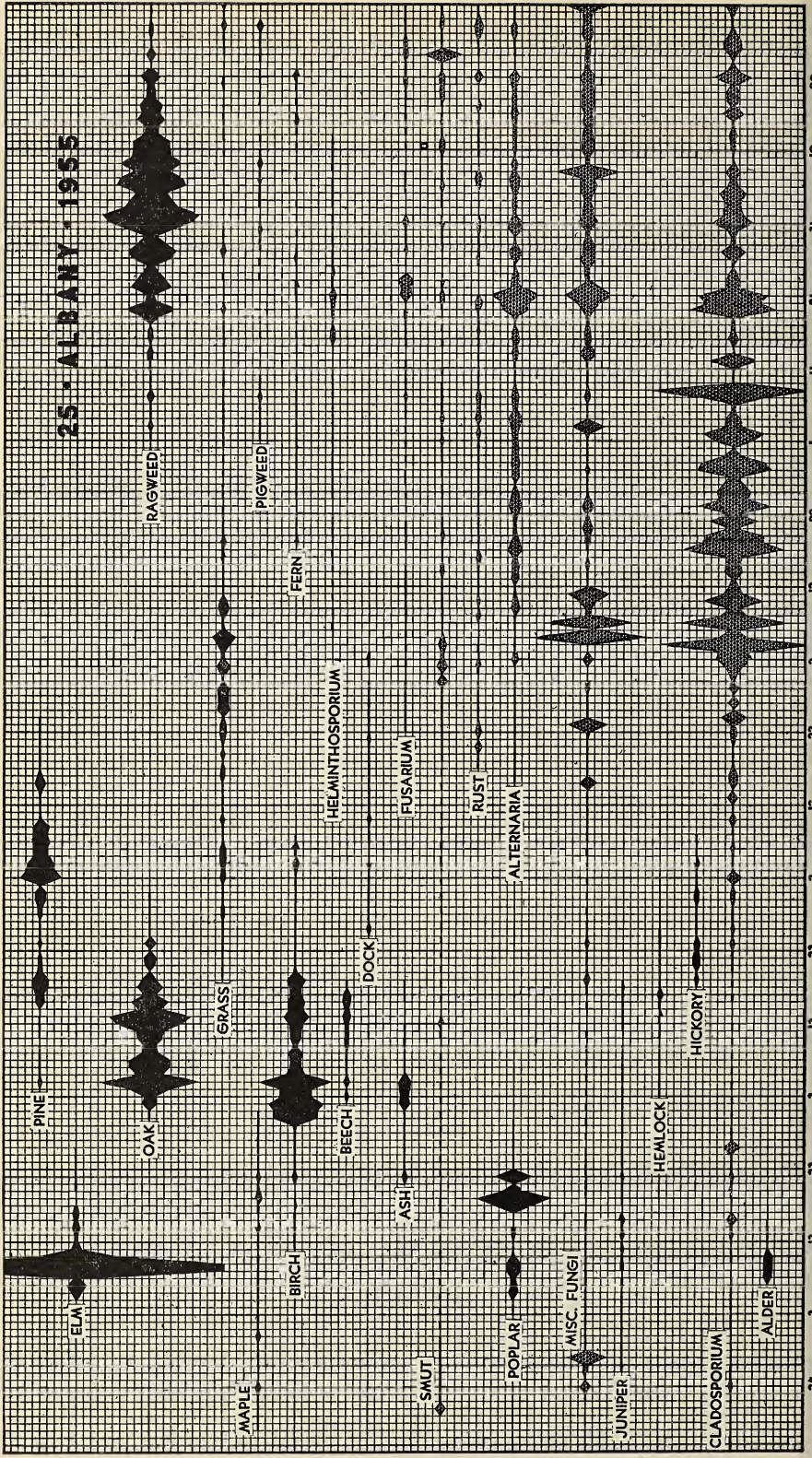
25 • ALBANY • 1954

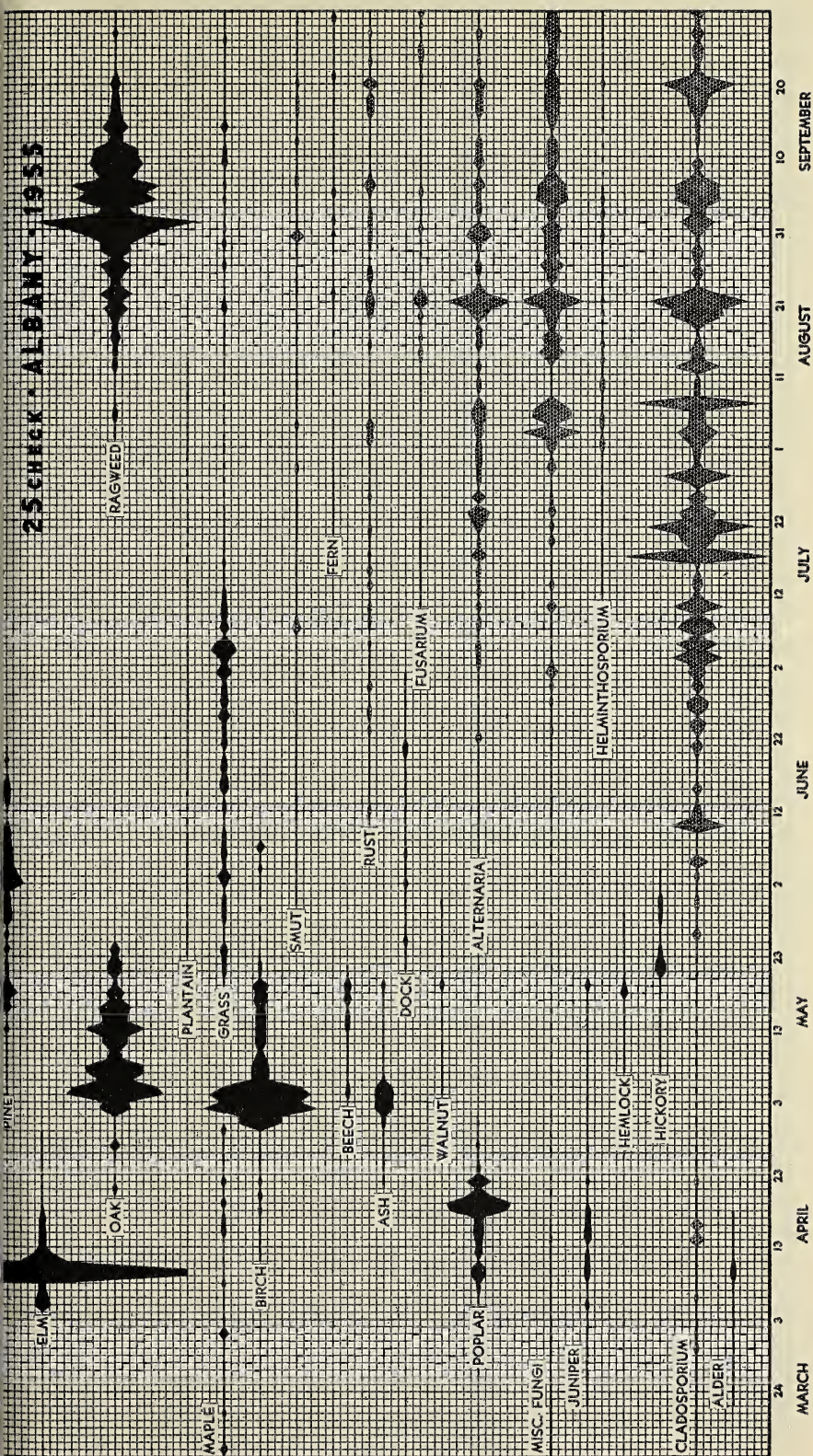


25A - ALBANY - 1954



25 • ALBANY • 1955





25 • ALBANY • 1953-4

ALTERNARIA

CLADOSPORIUM

MISC. FUNGI

PLANT HAIRS

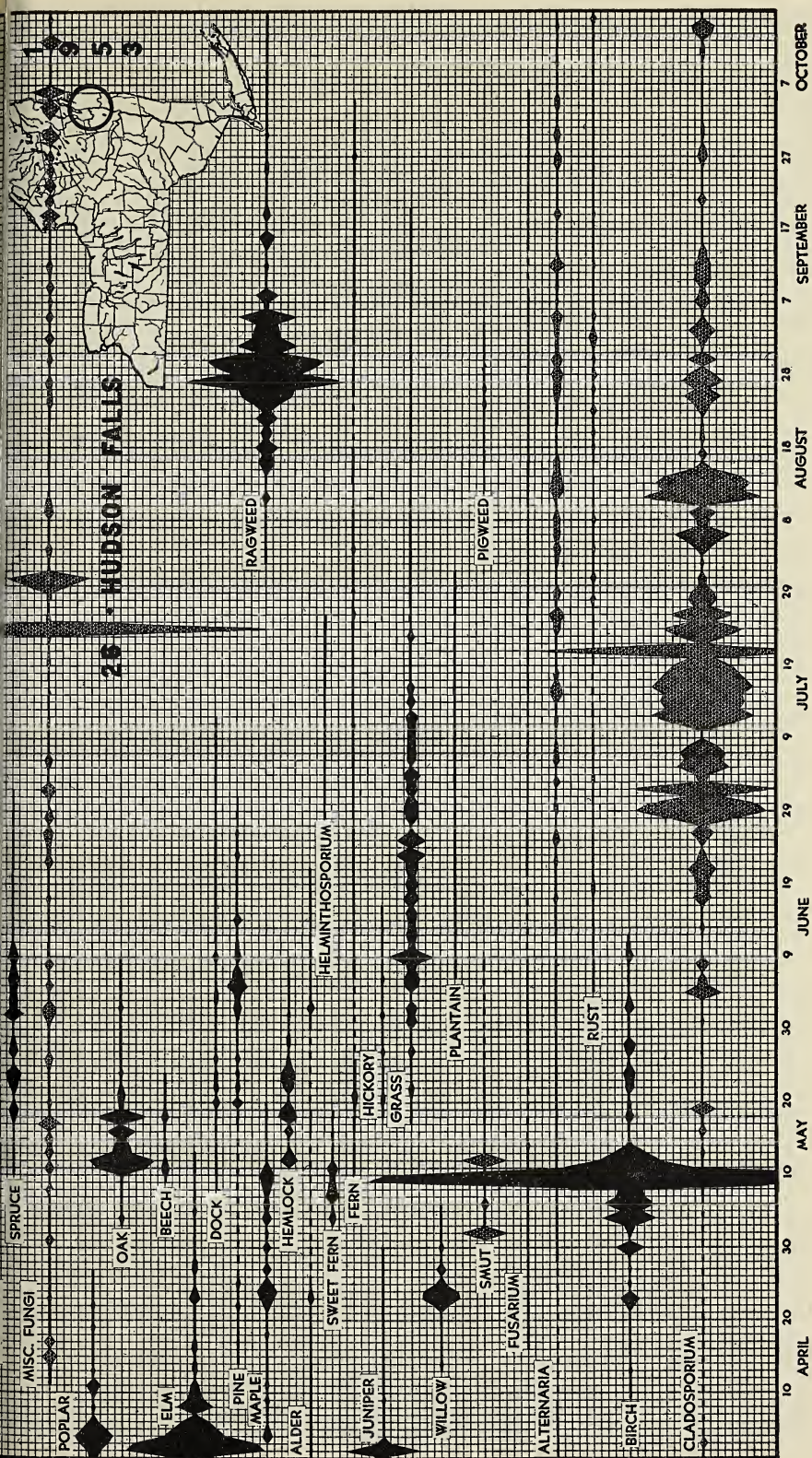
25A • ALBANY • 1953-4

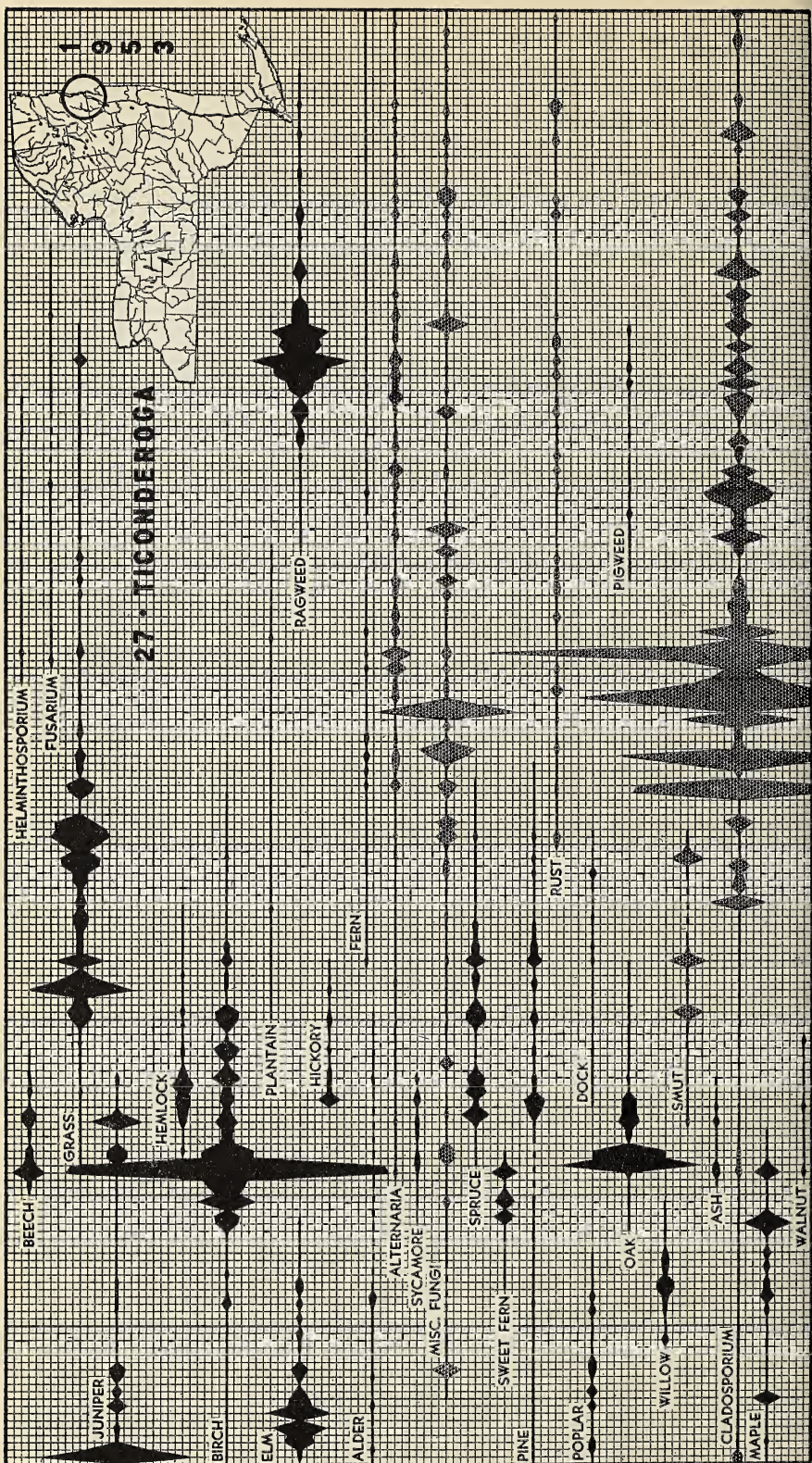
ALTERNARIA

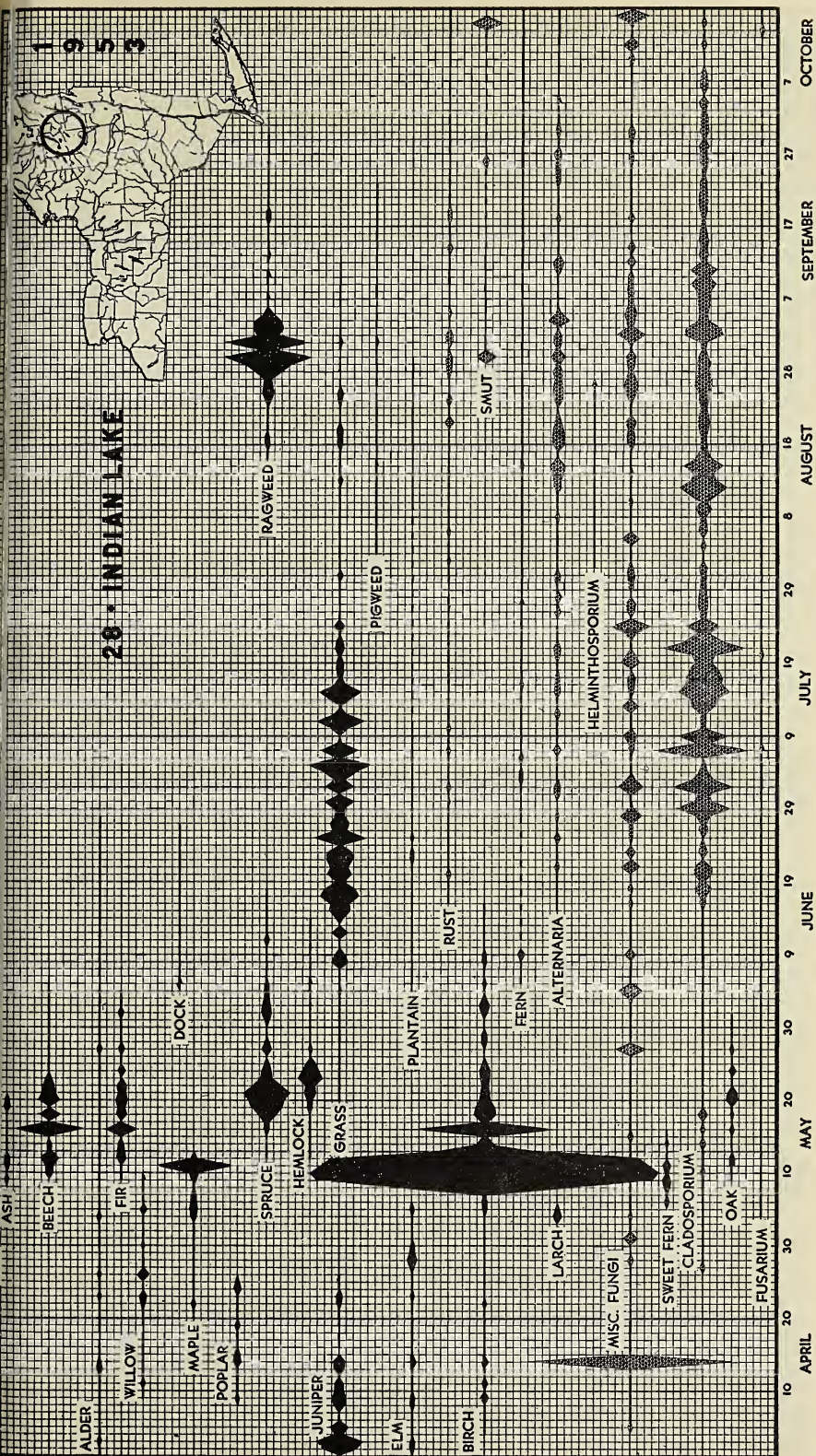
CLADOSPORIUM

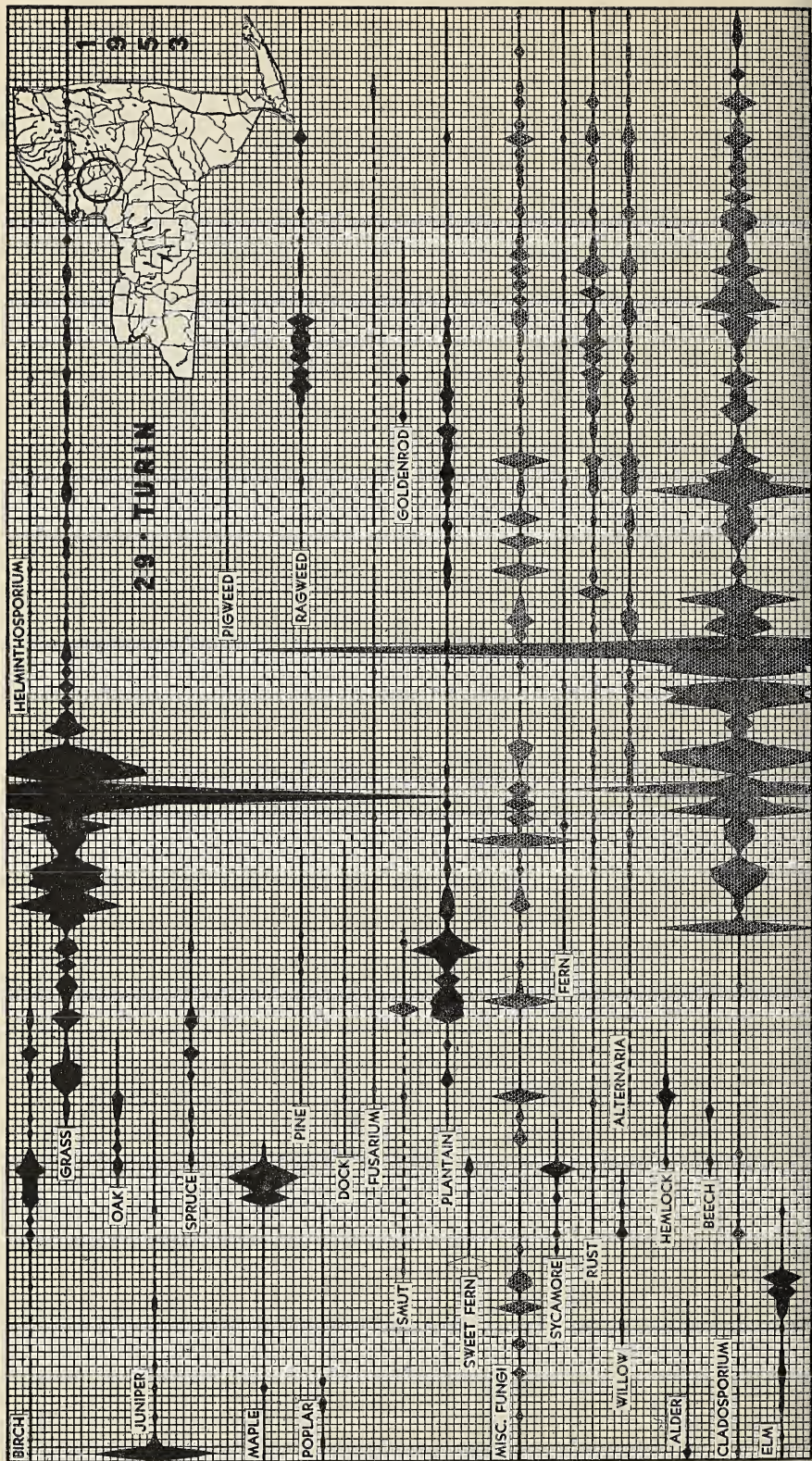
MISC. FUNGI

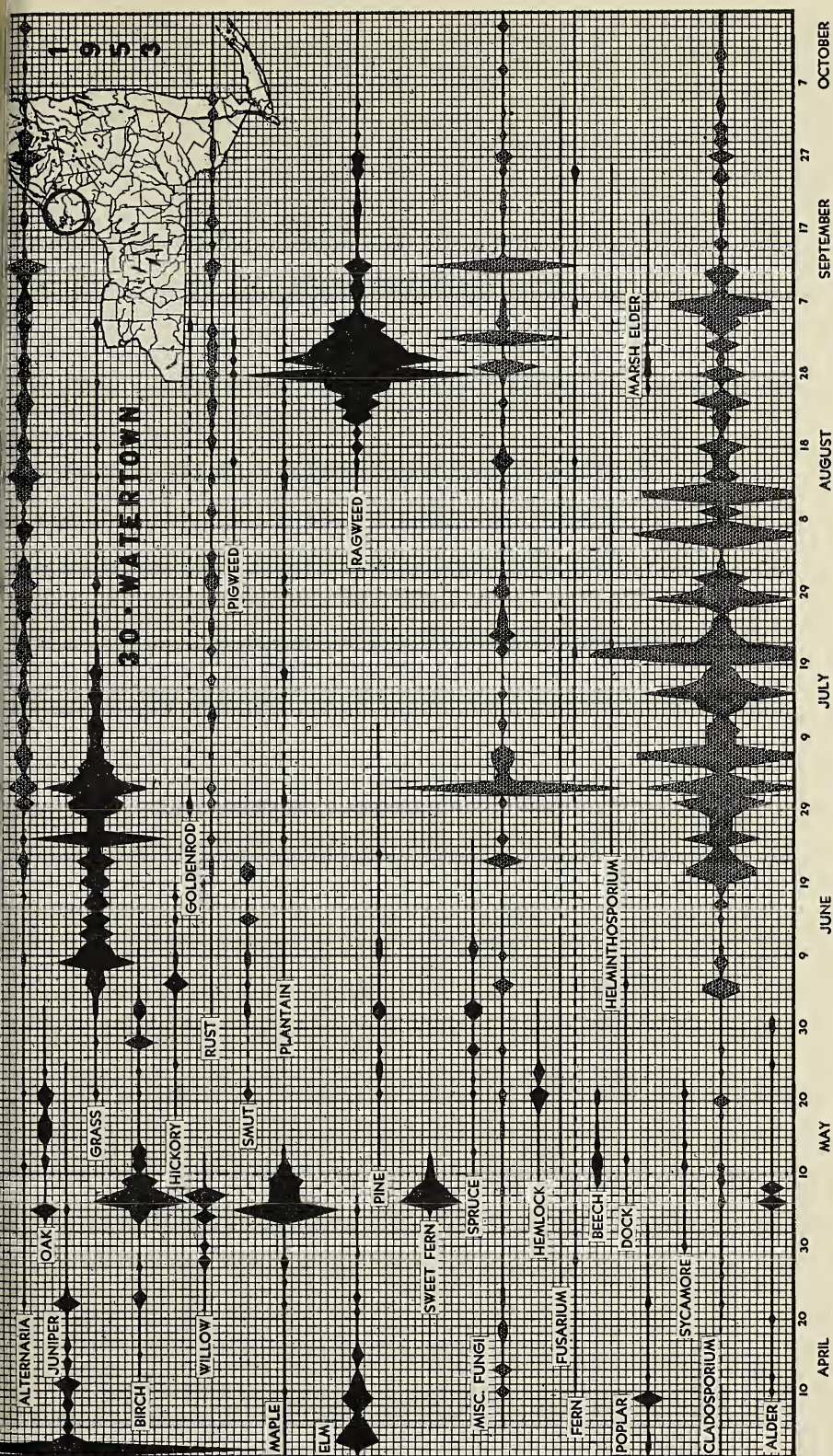
PLANT HAIRS

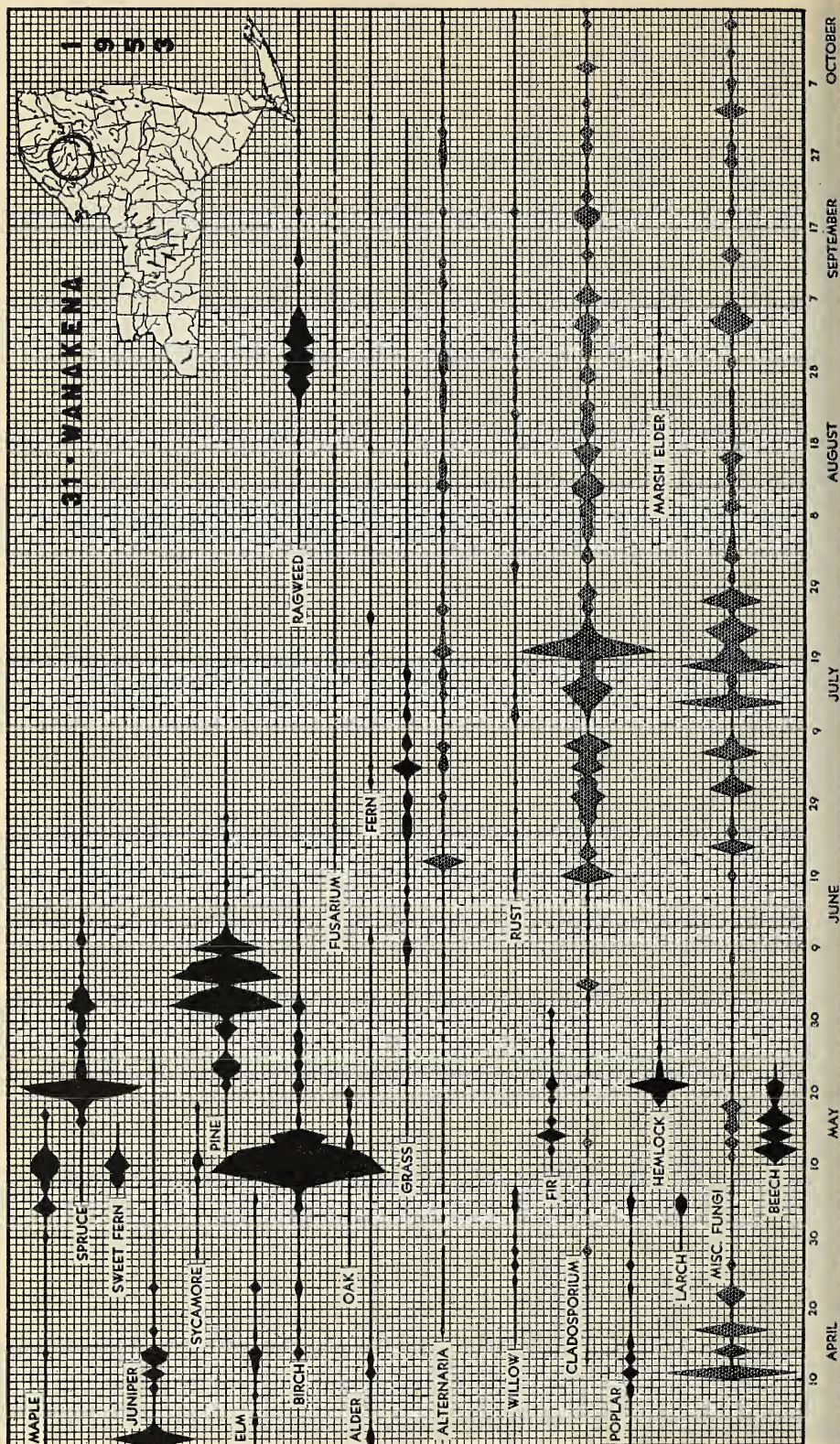






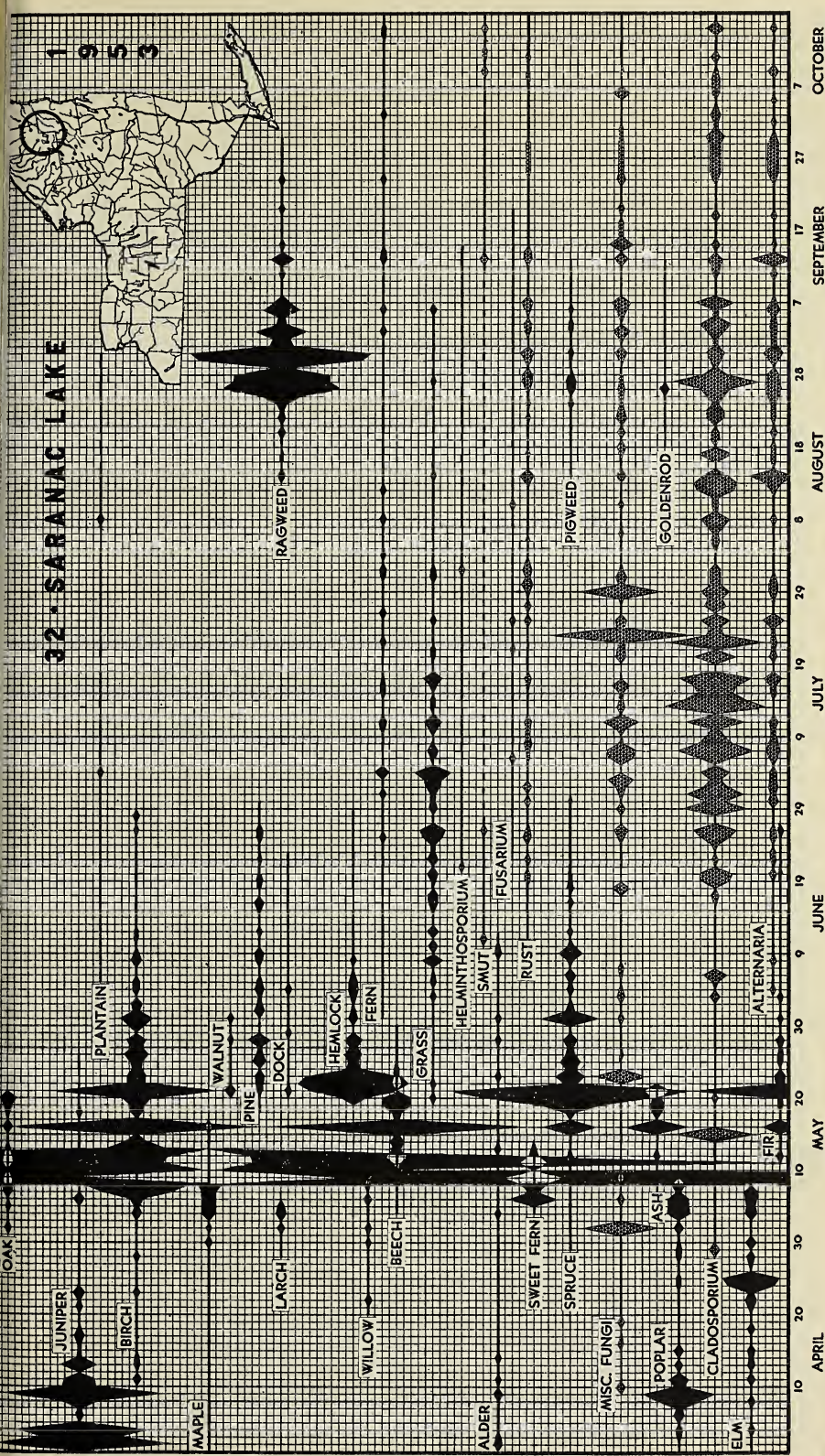


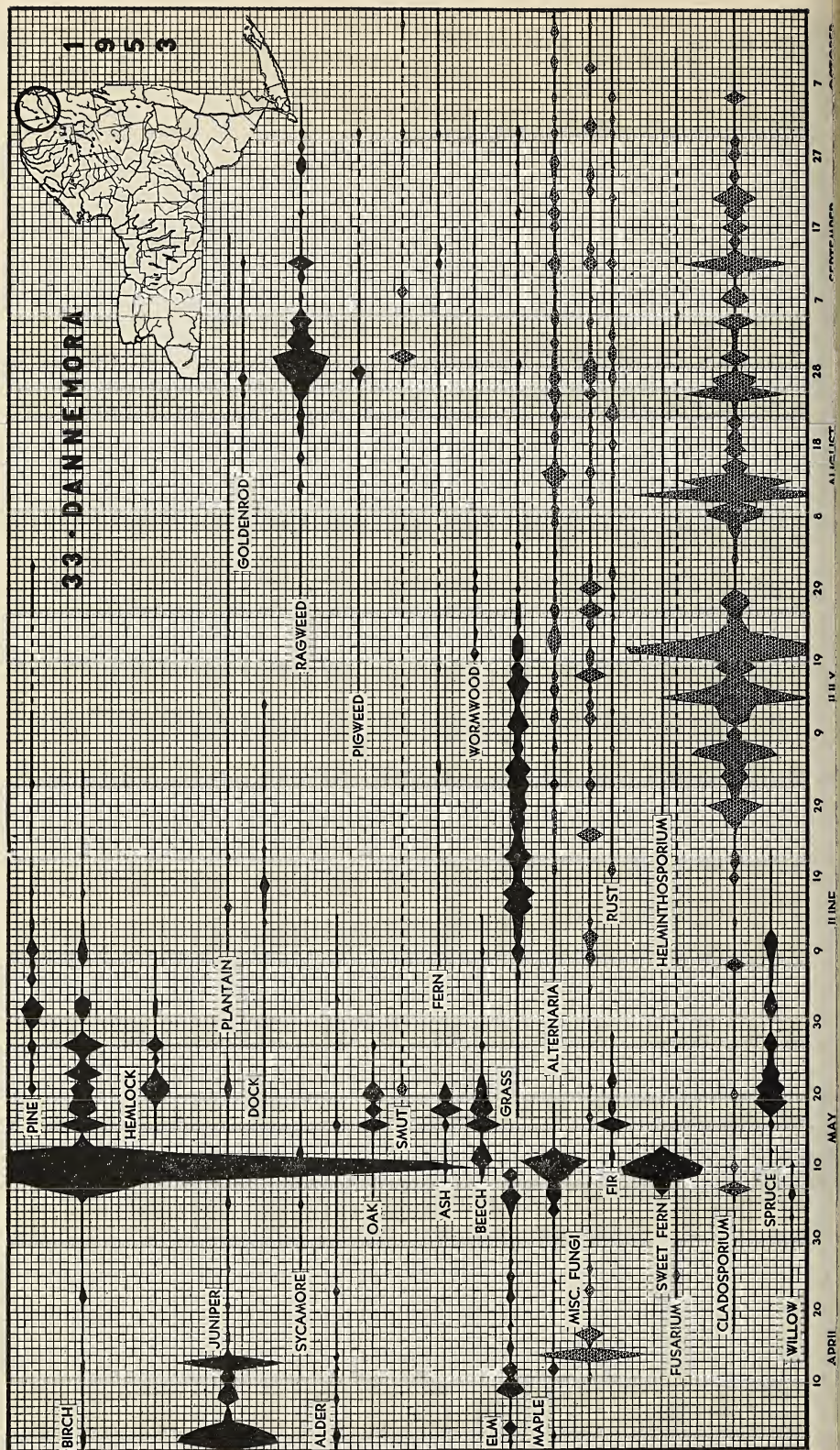


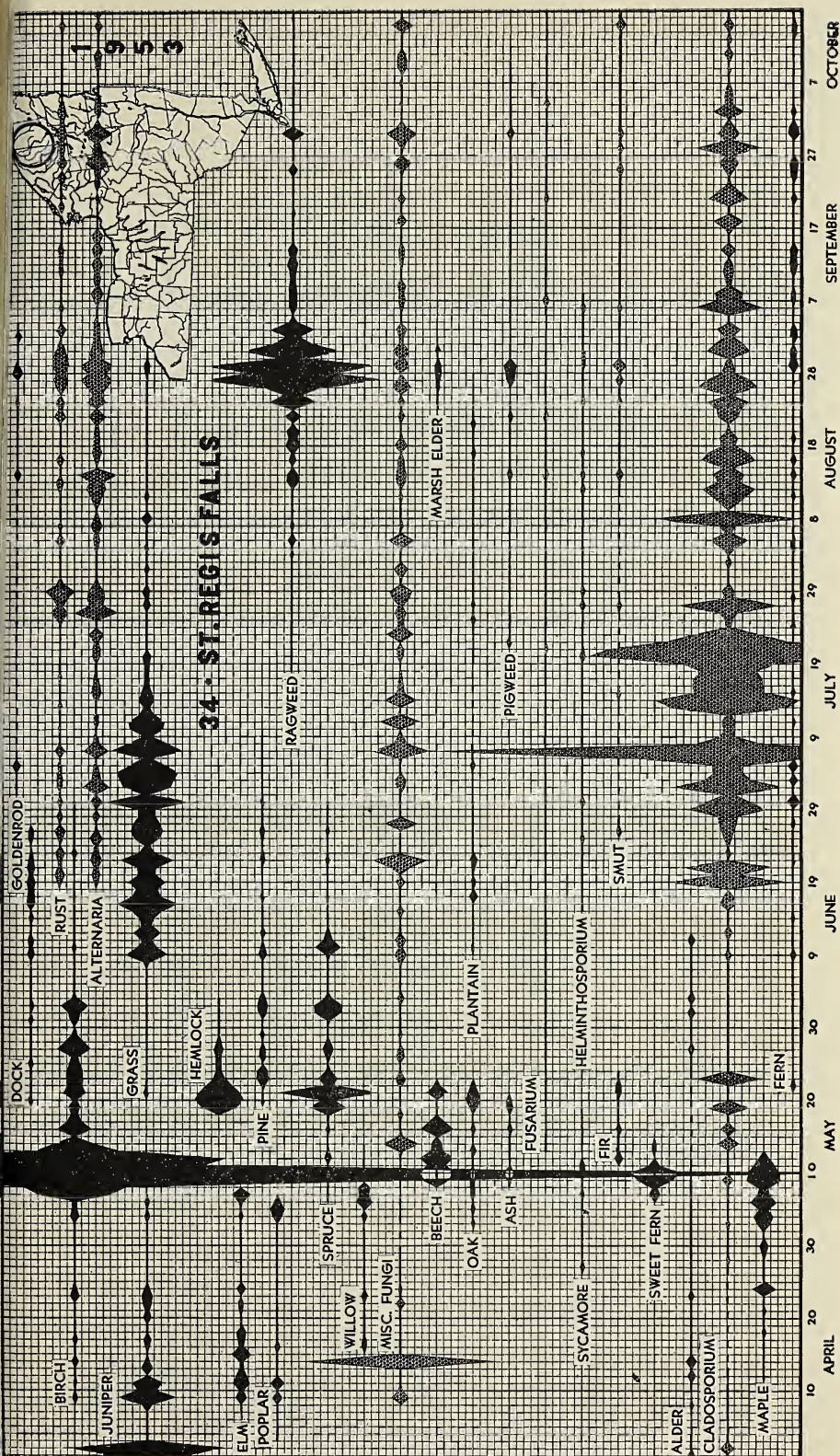


32 • SARANAC LAKE

1953

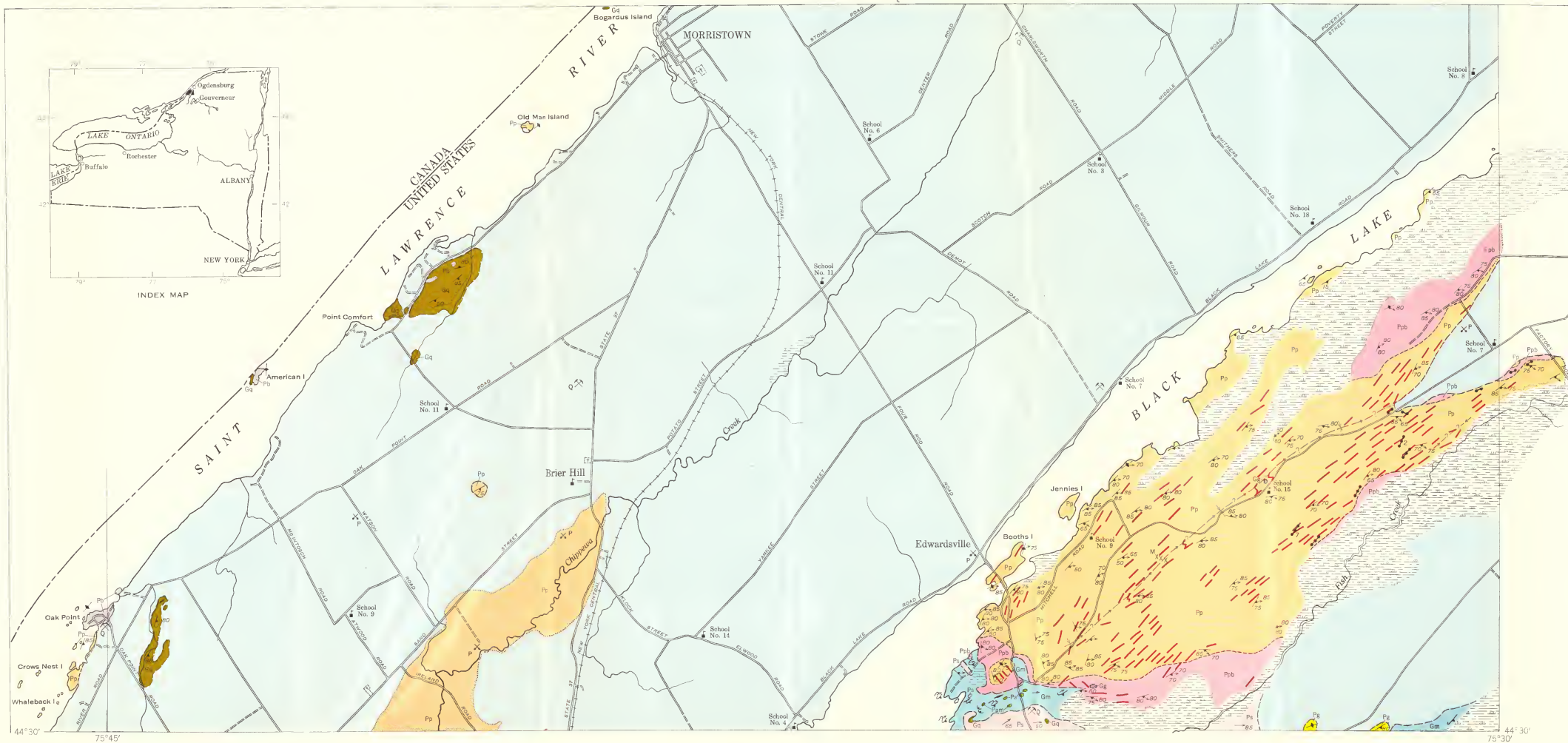






Pocket

3966



Adapted from Tennessee Valley Authority Topographic Map, 1942

Geology by R. V. Dietrich, 1949-50

E X P L A N A T I O N

11°12'
MAGNETIC NORTH
TRUE NORTH
APPROXIMATE MEAN DECLINATION 1942

PALEOZOIC

Ogdensburg dolomite (Ordovician), Theresa formation, Potsdam sandstone (Cambrian ?), undifferentiated

UNCONFORMITY

Basic dikes and sills
Diabase tabular bodies; some have basaltic borders

Aplite dikes and sills
Designated Pam where mylonitized

Amphibolized melanocratic gneisses
Crosscutting tabular bodies of amphibolite composition; some have fine-grained borders. Numerical indicates number of dikes.

PRECAMBRIAN

Alkalite gneiss
Pink, fine-grained

Trochilomites
Dark greenish-gray, medium-grained; occurs as border facies of one of the alkalite gneiss bodies.

Granite-basalt gneiss
Gray, medium-grained

Quartzite gneiss
Red, medium-grained, dark minerals have marked lineation.

PRECAMBRIAN

Basaltic granite
Pink and black, medium to coarse-grained; has an obscure foliation.

Melanocratic foliates
Each individual symbol represents many inclusions; the symbols appear as overprints on appropriately designated host rock; amphibolite, pyroxene plagioclase foliates, and intermediate types, many of which contain notable amounts of sillite, are included.

Garnet gneiss

Quartzite
White, buff, or gray, massive, usually pyritic; locally contains much introduced foldap; contains dikes and lenses of graphite and pegmatite.

PRECAMBRIAN

Marble
White, pure and impure varieties; locally contains disseminated sillite minerals and pegmatite lenses and nodules; diverse petrographic types occur as fragments in a tectonic breccia phase and as lenses within the unit.

Contact, dashed where covered

Inferred contact

Gradational contact

Syncline, showing trace of axial plane and plunge of axis

Strike and dip of foliation

Strike of vertical foliation

Bearing and plunge of lineation

Strike and dip of foliation and plunge of lineation

Dip, plunge and pattern of minor folds

Small prospect pit (magnetic)

Quarry

Sand and gravel pit

PRECAMBRIAN GEOLOGY OF THE BRIER HILL QUADRANGLE, NEW YORK

1 0 3 Miles

Workability, durability, strength and economy govern use of different building materials. Within this area, building materials are now used almost exclusively as aggregates for road building and road maintenance. Aggregates must be selected very carefully because they comprise the large part of both cement and bitumen base mixes. They must fulfill many physical and chemical requirements such as those related to strength (resistance, hardness, toughness), cementing value (particle shape, particle size gradation, surface texture), mineralogical composition, structure, porosity, density, light reflection and transmission properties and water absorption. For nearly all uses, construction engineers set up definite specifications for aggregates and they have readily accessible aggregate materials tested to determine their fitness. Rocks within the area that might serve as sources for aggregate have not been submitted to such physical and chemical tests by the writer; however, he has noted previous performance of aggregates and has made petrographic studies of these rocks.

Within this and adjacent areas, quartzite¹, quartz syenite² gneiss³, alaskite⁴ gneiss, melanocratic⁵ gneiss, sandstone from the Potsdam and Theresa formations, Ogdensburg dolomite⁶ and unconsolidated sand and gravel have been used as building material and aggregate. The quartzite, quartz syenite gneiss, alaskite gneiss and melanocratic gneiss have locally undergone marked cataclasis⁷ and thus are not satisfactory aggregates for many uses. Sandstone occurring in some parts of the Brier Hill quadrangle is a fair to good aggregate; locally it is a very unsatisfactory aggregate because it crumbles readily. The Ogdensburg dolomite is a very suitable aggregate for most purposes. Sand and gravel from all deposits ranges greatly in particle size and shape and in composition. Some of it is of poor quality because of high clay and/or high organic content; some of it is good clean sand and gravel. The most used aggregates, dolomite and sand and gravel, are described more fully below from the viewpoint of aggregate utility.

Fresh unweathered samples of Ogdensburg dolomite have been collected from outcrops, quarry walls and quarry crush fractions. The Ogdensburg formation is made up chiefly of alternating beds of thin-bedded, brown-gray, fine-grained dolomite and thick-bedded gray, granular dolomite with sporadic calcareous and calc-sandy beds near its base. Locally, the formation is veined by carbonates and pyrite.

The dolomite is easily procured. In most places the cover is not of great thickness; the rock is jointed throughout; it is present near main highways; it is near ample water supplies that could be used for washing.

Most Ogdensburg formation aggregate is now being used for bitumen mixes, though it is considered good aggregate for both macadam and concrete. The presence of deleterious pyrite and the presence within the smaller crush fractions of many lath-shaped particles may be considered undesirable. However, pyrite is present only locally, and even in such places in small amounts; pyrite-bearing dolomite can be avoided altogether if care is taken in locating quarries. Also, no ill effects attributable to lath-shaped particles in the aggregate have become apparent to date. Aggregates from the Ogdensburg dolomite are generally sharp, angular and hard. All interrogated engineers report that the aggregates have very good wearing qualities. They attribute difficulties such as those apparent during the freezing and thawing seasons to the time of placing of mixes the protection afforded mixes after placing (during inclement weather) and drainage conditions rather than to inherent aggregate weaknesses.

EXPLANATION

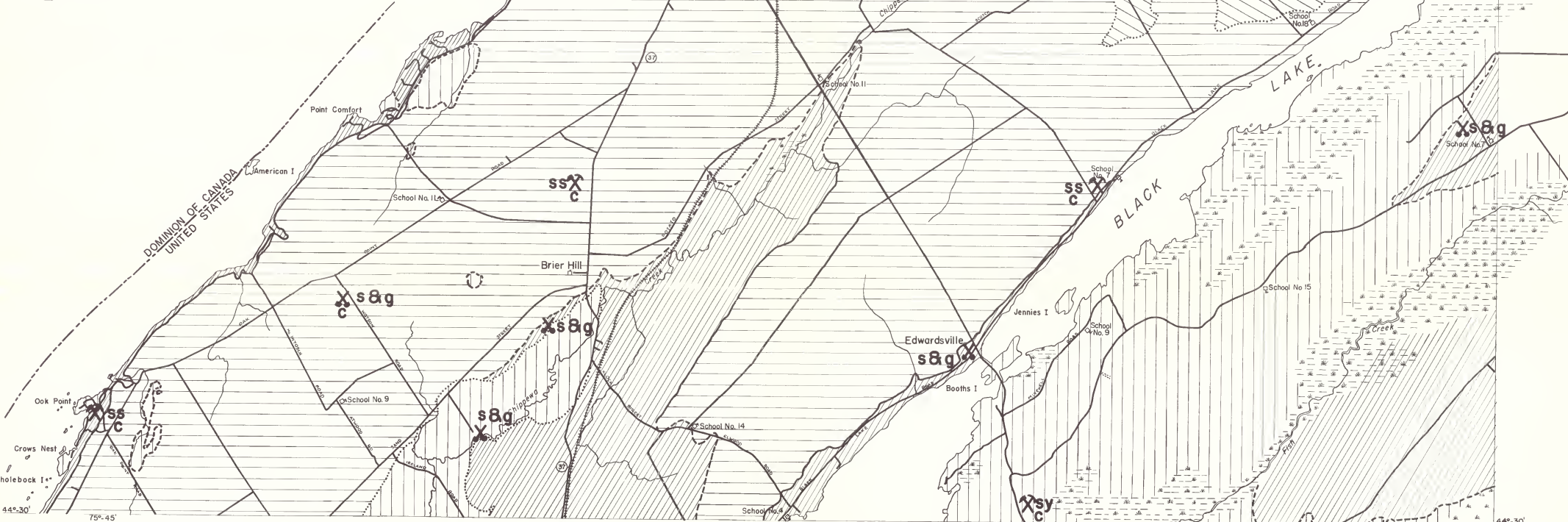
- quarry
- pit
- not being worked at present
- sandstone
- dolomite
- quartz syenite
- sand and gravel

PALEOZOIC

- Ogdensburg dolomite (thick beds of blue-gray granular dolomite alternating with thin-bedded iron-gray fine-grained dolomite; a few gray calcareous sandstone layers occur near base.)
- Theresa formation (gray and buff sandy limestones, white sandstone and gray calcareous sandstone in alternate strata.)
- Potsdam sandstone (white, red, buff, or color-laminated vitreous sandstone; lenses of concretions, and breccias and conglomerates consisting chiefly of quartzite fragments occur locally.)

PRECAMBRIAN

- Crystalline rocks



Adapted from
Tennessee Valley Authority
Topographic Map, 1942

PITS & QUARRIES IN BRIER HILL QUADRANGLE, NEW YORK

Geology by
R. V. Dietrich, 1949-50

1 0 1 2 3 4 Miles

11° 2' 30" NORTH
APPROXIMATE MEAN
DECLINATION 1942

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